

CHAPTER 1

CONSTRUCTION METHODS AND MATERIALS: HEAVY CONSTRUCTION

As a general rule, the term *heavy construction* refers to the type of construction in which large bulks of materials and extra-heavy structural members are used, such as steel, timber, concrete, or a combination of these materials. In the Naval Construction Force, heavy construction includes the construction of bridges, waterfront structures, and steel frame structures.

The Seabee's construction functions, in support of the Navy's and Marine Corps' operating forces, might include the design and construction of these various structures or their rehabilitation; therefore, you, as an EA, should understand the terminology, the basic principles, and the methodology used in the construction of these facilities. Your knowledge of the methods and materials used in heavy construction will greatly assist you in the preparation of engineering drawings (original, modified, or as-built).

This chapter will discuss basic heavy construction methods and materials.

BRIDGE CONSTRUCTION

A bridge is a structure used to carry traffic over a depression or an obstacle, and it generally consists of two principal parts: the lower part, or **substructure**; and the upper part, or **superstructure**. When a bridge is supported only at its two end supports, or **abutments**, it is called a **single-span bridge**. A bridge that has one or more intermediate supports, such as the one shown in figure 1-1, is known as a **multispan bridge**. Although bridges may be either fixed or floating, only fixed bridges will be discussed in this training manual (TRAMAN). The following is a discussion of the components of a fixed bridge.

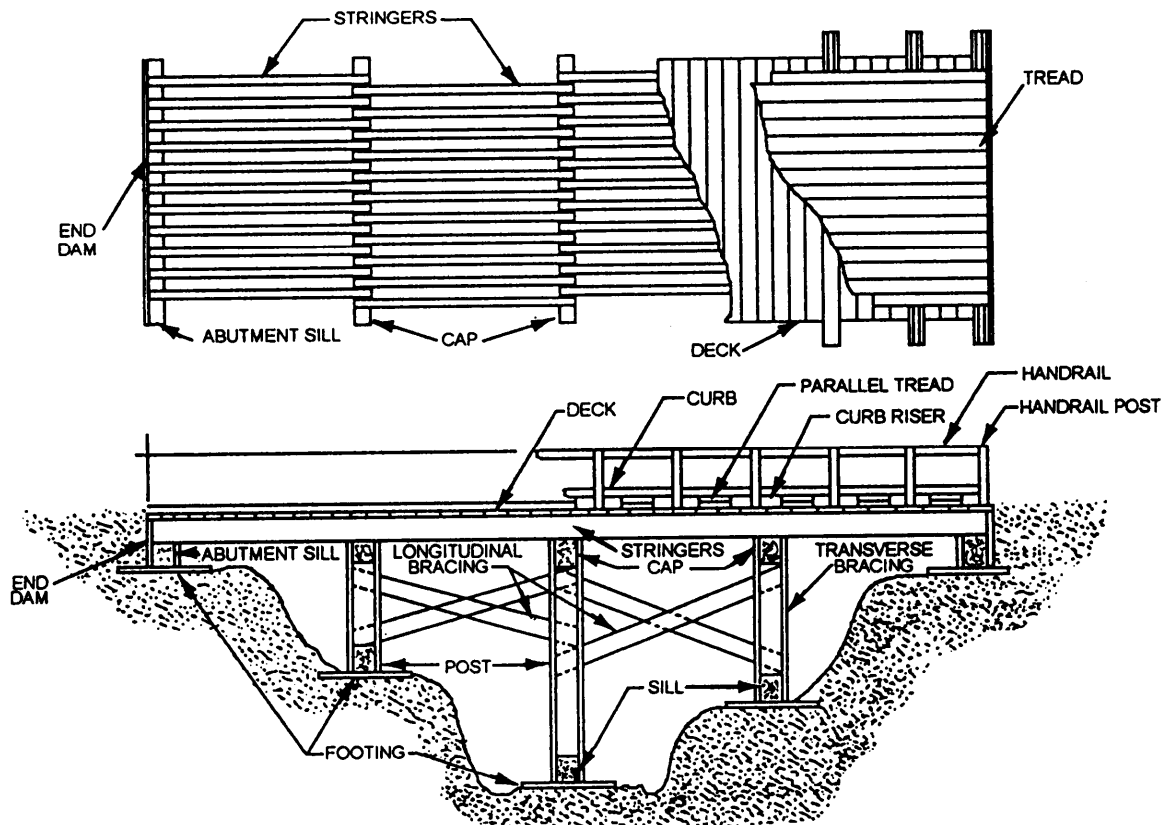


Figure 1-1.—A multispan (trestle-bent) bridge.

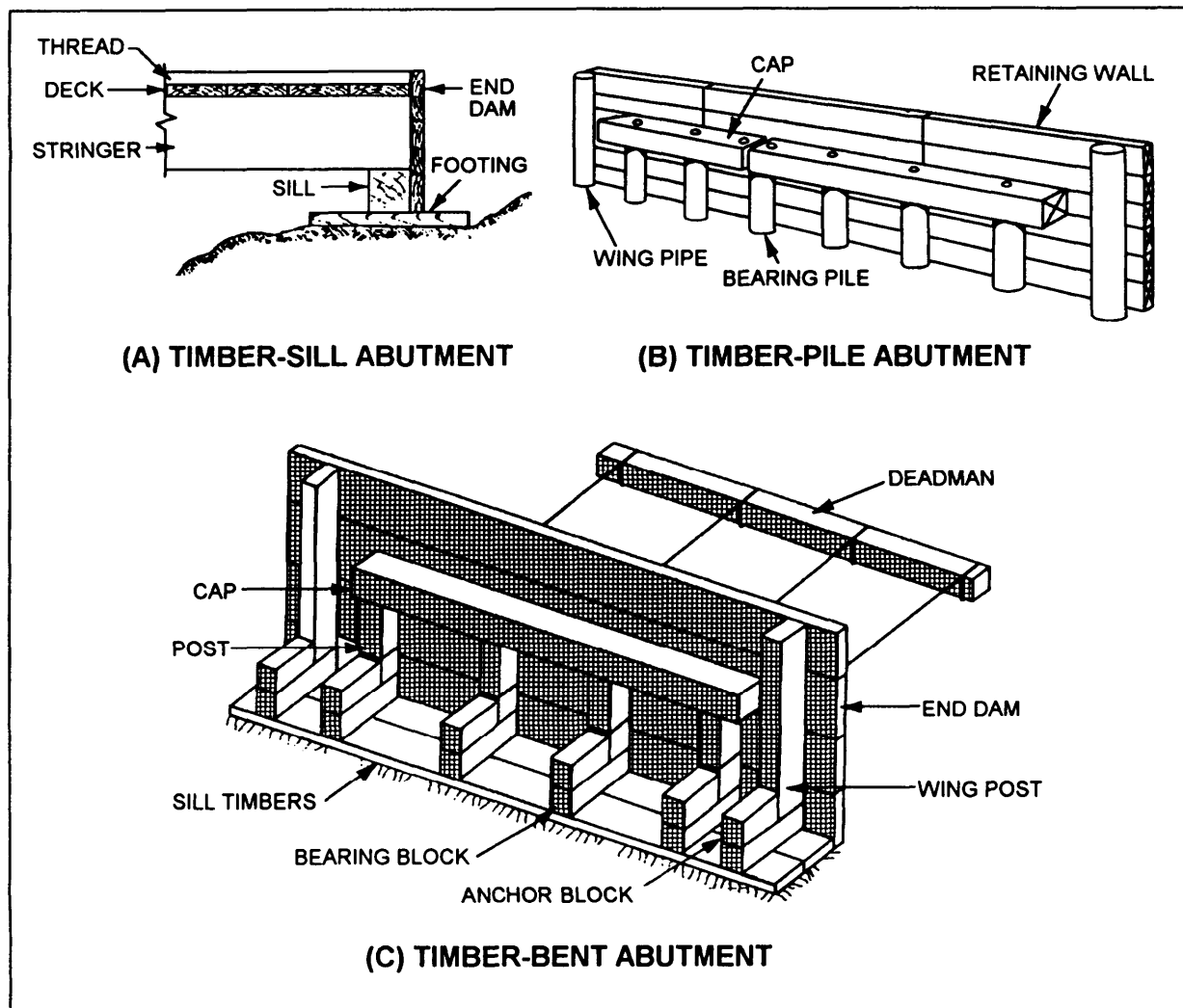


Figure 1-2.—Types of fixed-bridge abutments.

ABUTMENTS

There are different types of fixed bridge abutments. First, let us discuss the **footing-type** abutment. In figure 1-2, views A and C show two types of footing abutments. View A shows a timber-sill abutment, and view C shows a timber-bent abutment. By studying both of these views, you should see that there are three elements that are common to a footing-type abutment. Each type has a footing, a sill, and an end dam.

If you will notice, the timber-sill abutment shown in figure 1-2, view A, is the same footing-type abutment that is shown for the bridge in figure 1-1. In this type of abutment, loads are transmitted from the bridge stringers to the **sill**, which, in turn, distributes the load to the **footing**. The footing then distributes the combined load over a sufficient area to keep the support from sinking into the ground. The **end dam** is a wall of planks that keeps the approach-road backfill from caving in

between the stringers. The timber-sill abutment should not be more than 3 feet high. It can be used to support spans up to 25 feet long.

The timber-bent abutment shown in figure 1-2, view C, can be used with timber or steel stringers on bridges with spans up to 30 feet. The **deadman** is used to provide horizontal stability. These abutments do not exceed 6 feet in height.

Other types of fixed-bridge abutments are **pile** abutments and **concrete** abutments. Timber- or steel-pile abutments can support spans of any length, can be used with steel or timber stringers, and can reach a maximum height of 10 feet. A timber-pile abutment is shown in figure 1-2, view B. Concrete abutments are the most permanent type. They may be mass or reinforced concrete, can be used with spans of any length, and can be as high as 20 feet. They may be used with either steel or timber stringers.

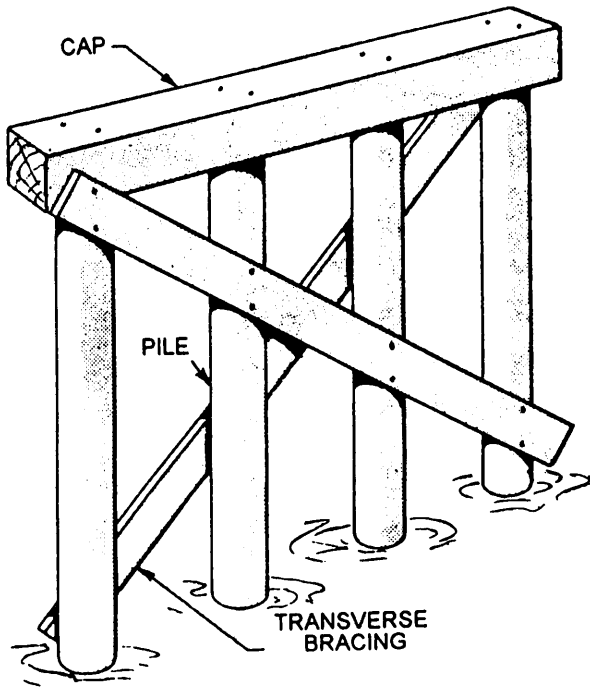


Figure 1-3.—Typical pile bent.

INTERMEDIATE SUPPORTS

Bents and piers provide support for the bridge superstructure at points other than the bank ends. A **bent** consists of a single row of posts or piles, while a **pier**

consists of two or more rows of posts or piles. The following text discusses some of the different types of bents and piers.

The pile bent shown in figure 1-3 consists of the bent cap, which provides a bearing surface for the bridge stringers, and the piles, which transmit the load to the soil. The support for the loads may be derived either from column action when the tip of the pile bears on firm stratum, such as rock or hard clay, or from friction between the pile and the soil into which it is driven. In both cases, earth pressure must provide some lateral support, but traverse bracing is often used to brace the bent laterally.

A timber pile bent consists of a single row of piles with a pile cap. It should be braced to the next bent or to an abutment to reduce the unbraced length and to provide stability. This bent will support a combined span length of 50 feet

The trestle bent shown in figure 1-4 is similar to the pile bent except that the posts, taking the place of the piles, transmit the load from the cap to the sill. The sill transmits the load to the footings, and the footings transmit the load to the soil. Timber trestle bents are normally constructed in dry, shallow gaps in which the soil is firm. They are not suitable for use in soft soil or swift or deep streams. The bent can support a combined span length of up to 30 feet and can be 12 feet high.

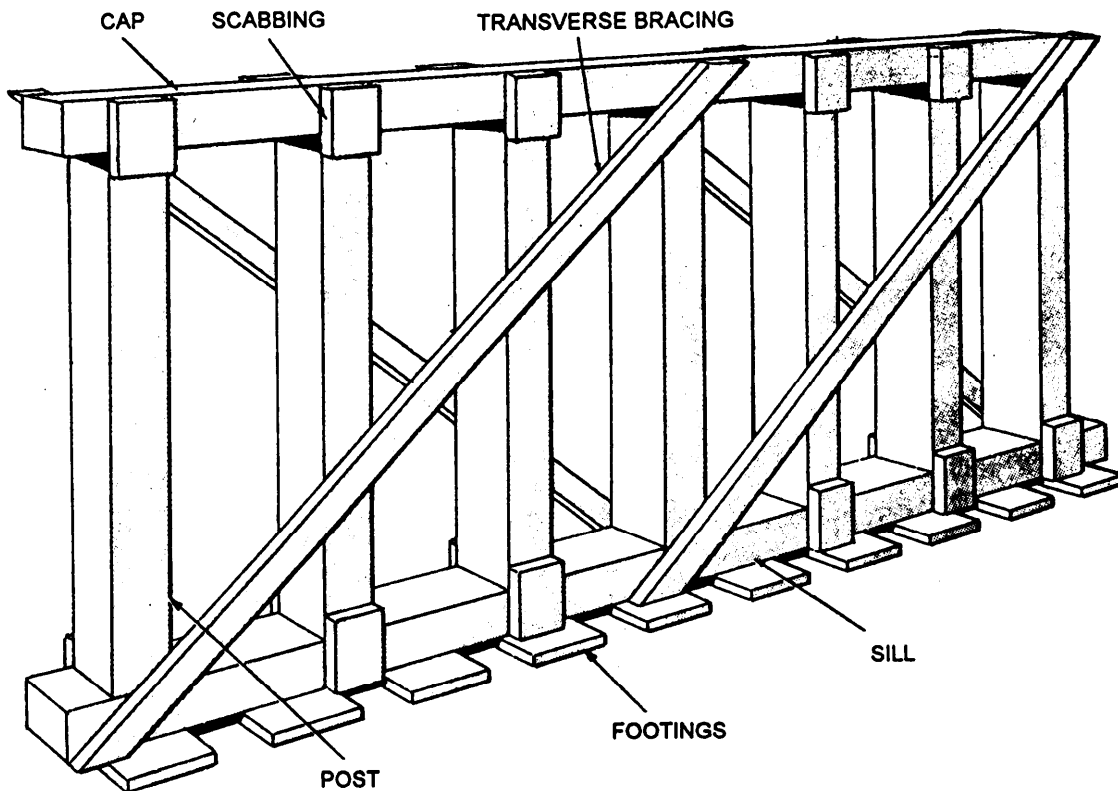


Figure 1-4.—Timber trestle bent.

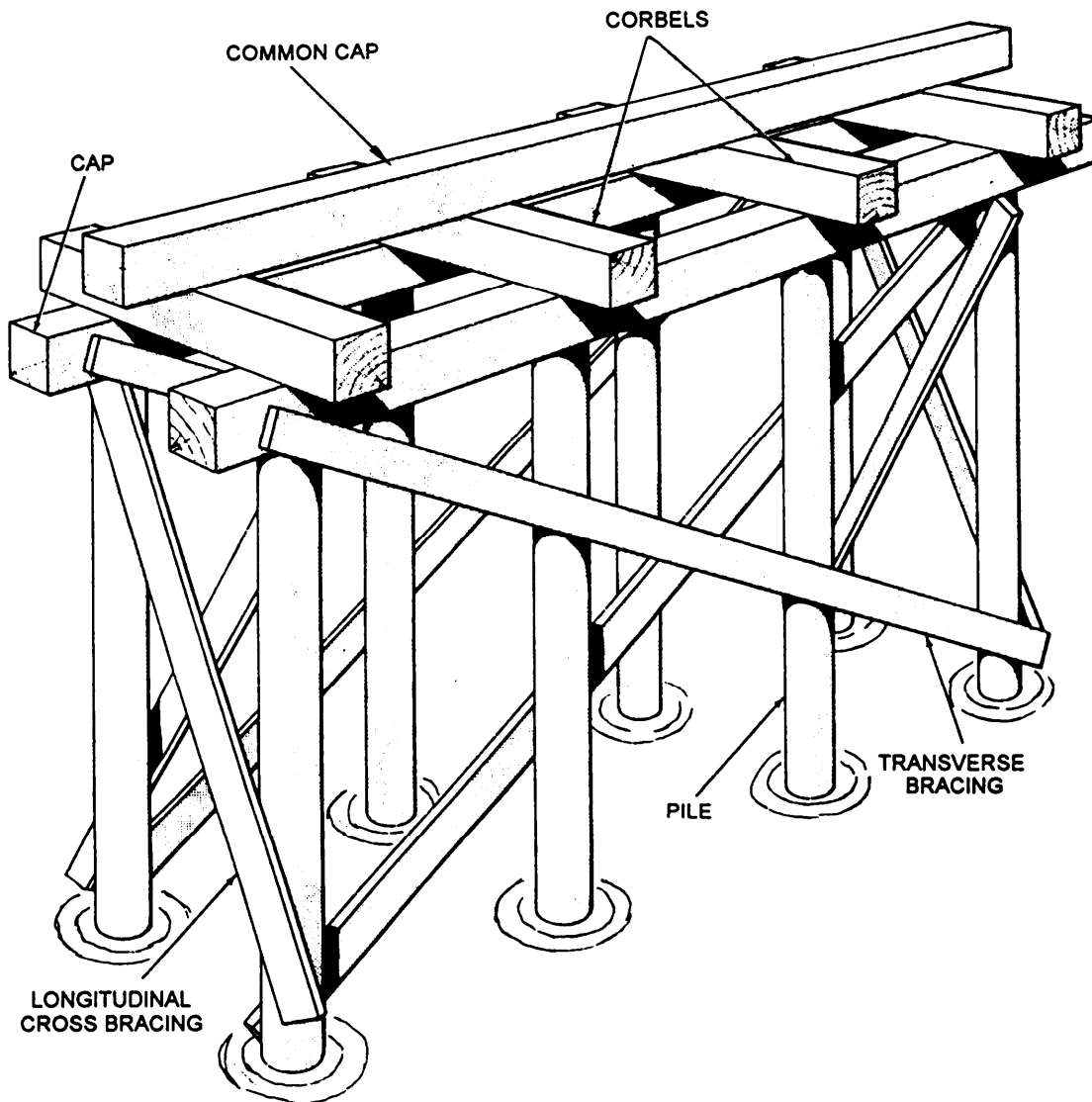


Figure 1-5.—Typical pile pier.

The pile pier (fig. 1-5) is composed of two or more pile bents. In this figure, notice the common cap. The cap transmits the bridge load to the **corbels**, which in turn, transmit the combined load to the individual bent caps. Piers are usually provided with cross bracing that ties the bents together and provides rigidity in the longitudinal direction.

SUPERSTRUCTURE

The superstructure of a bridge consists of the stringers, flooring (decking and treads), curbing, walks, handrails, and other items that form the part of the bridge above the substructure. Figure 1-6 is an illustration of a superstructure.

As seen in the figure, those structural members resting on and spanning the distance between the intermediate supports or abutments are called **stringers**. The stringers are the mainload-carrying members of the superstructure. They receive the load from the flooring and transmit it to the substructure. Although the figure shows both steel and timber stringers, in practice only one type would normally be used.

The flooring system includes the deck; the wearing surface, or tread, that protects the deck; and the curb and handrail system. The plank deck is the simplest to design and construct, and it provides considerable savings in time compared to other types of decks. Plank decking is normally placed perpendicular to the bridge center line (direction of traffic) for ease and speed of construction. A better arrangement, however, is provided if the decking is placed at about a 30- to 60-degree skew to

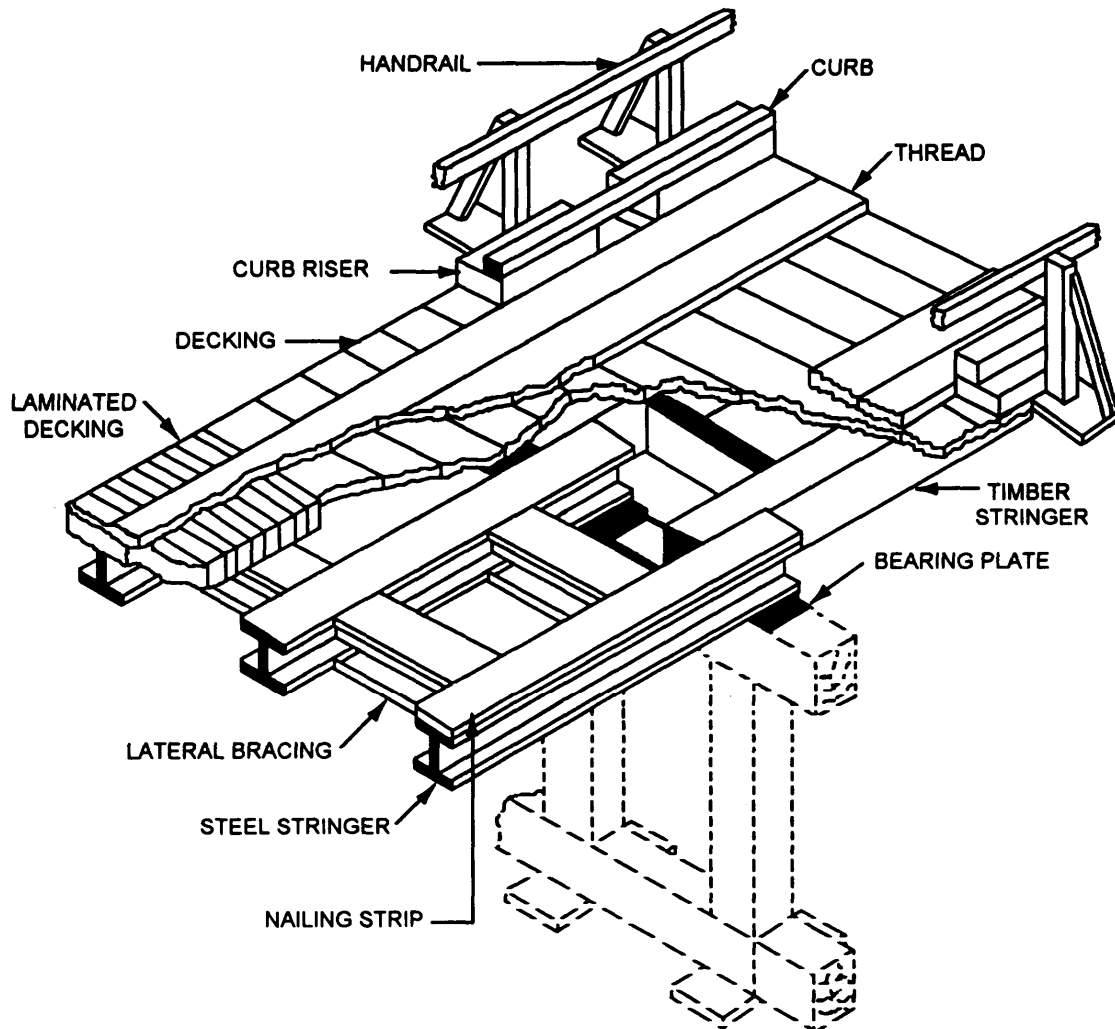


Figure 1-6.—Nomenclature of a fixed highway bridge superstructure.

the center line. A space of approximately one-quarter inch should be provided between the planks to allow for swelling, to provide water drainage, and to permit air circulation. The **minimum** thickness of decking is 3 inches in all cases; however, when the required thickness of plank decking exceeds 6 inches, then a laminated type of decking should be used.

FOUNDATIONS AND PILES

That part of a building or structure located below the surface of the ground is called the **foundation**. Its purpose is to distribute the weight of the building or structure and all live loads over an area of subgrade large enough to prevent settlement and collapse.

A **pile** is a slender structural unit driven into the ground to transmit loads to the underground strata. It transfers loads to the surrounding underground strata by friction along its surface or by direct bearing on the

compressed soil at or near the bottom. A **bearing pile** sustains a downward load and may be driven vertically or otherwise; however, when a bearing pile is driven other than vertically, it is known as a **batter pile**. Another type of pile is the sheet pile. It is used to resist lateral soil pressure.

The following discussion is intended to introduce and familiarize you with some of the common types of foundations and piles that you may be required to include in your construction drawings.

FOUNDATIONS

In general, all foundations consist of three essential parts: the **foundation bed**, which consists of the soil or rock upon which the building or structure rests; the **footing**, which is normally widened and rests on the foundation bed; and the **foundation wall**, which rises from the foundation to a location somewhere above the

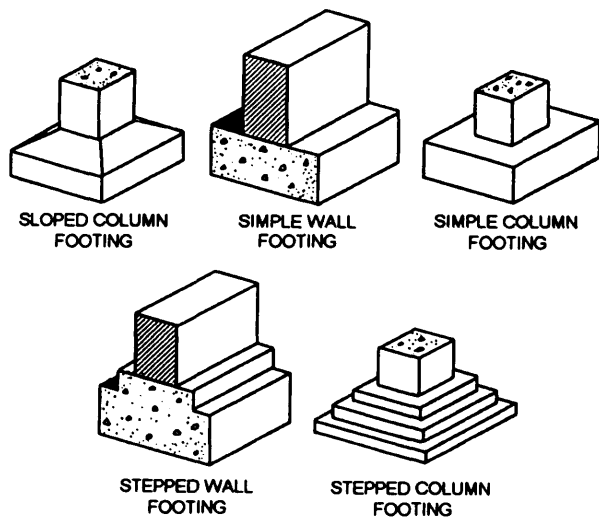


Figure 1-7.—wall and column foundations.

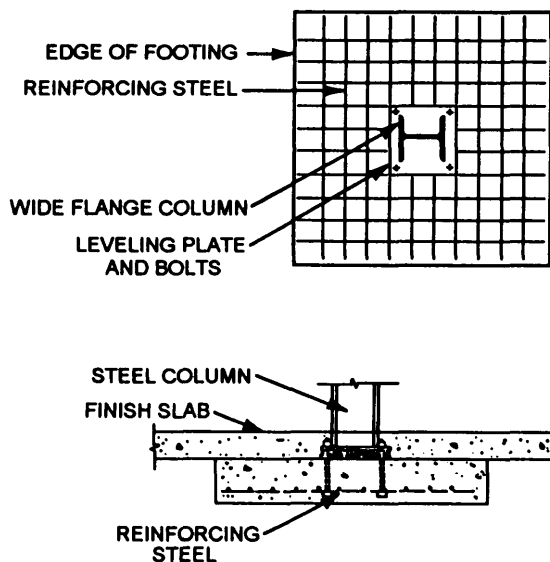


Figure 1-8.—Plan and section of a typical spread footing.

ground. The foundation wall, contrary to its name, may be a column or a pedestal instead of a wall. But, when it is a wall, it forms what is known as a **continuous foundation**. Figure 1-7 shows common types of wall and column foundations.

The continuous foundation is the type of foundation that is most commonly used for small buildings. The size of the footing and the thickness of the foundation wall are specified on the basis of the type of soil at the site. Most building codes also require that the bottom of the footing be horizontal and that any slopes be compensated for by stepping the bottom of the footing.

Another type of foundation is the **grade-beam foundation**. A **grade beam** is a reinforced concrete

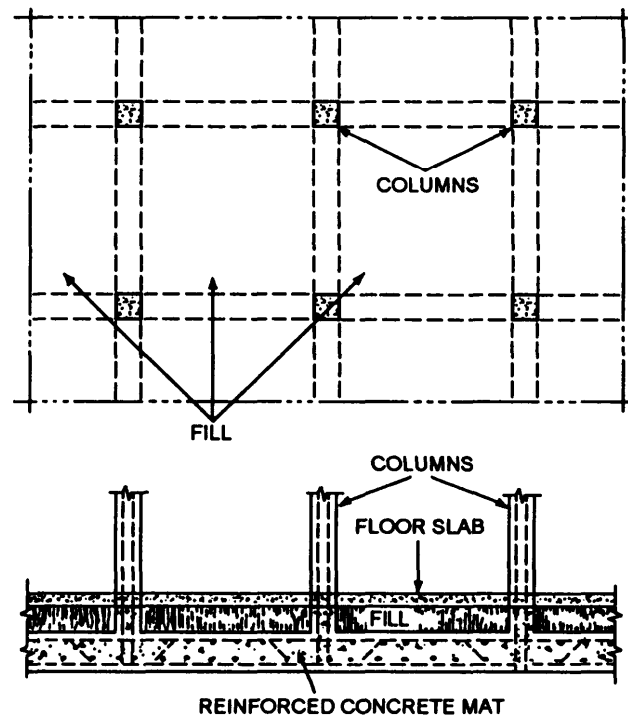


Figure 1-9.—Plan and section of a mat foundation.

beam located at grade level around the entire perimeter of a building, and it is supported by a series of concrete piers extending into undisturbed soil. The building loads are supported by the grade beam, which distributes the load to the piers. The piers then distribute the load to the foundation bed

A **spread foundation**, such as the one shown in figure 1-8, is often required where heavy concentrated loads from columns, girders, or roof trusses are located. This type of foundation may be located under isolated columns or at intervals along a wall where the concentrated loads occur. Spread footings are generally reinforced with steel. They may be flat, stepped, or sloped, such as shown in figure 1-7.

Figure 1-9 shows the plan and section of a typical **mat foundation**. In this type of foundation, a heavily reinforced concrete slab extends under the entire building and distributes the total building load over the entire site. This minimizes problems created by unequal settlement when the subsoil conditions are uneven. The mat foundation is often referred to as a **floating foundation**.

PILE CONSTRUCTION

Piles include many different types and materials. The following text discusses the more common types.

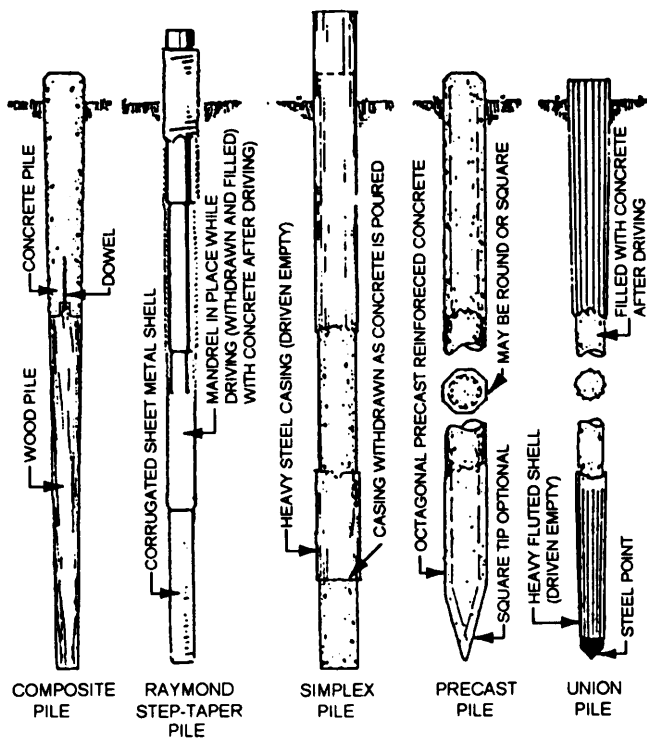


Figure 1-10.—Types of concrete piles.

Bearing Piles

Timber bearing piles are usually straight tree trunks with the limbs and bark removed. These piles, if kept continuously wet, will last for centuries; however, they are used for low design loads because of their vulnerability to damage while they are being driven into the ground. The small end of the pile is called the tip; the larger end is called the butt. Timber piles range from 16 to 90 feet in length with a tip diameter of at least 6 inches. The butt diameter is seldom less than 12 inches.

A steel bearing pile might be an H-pile (having an H-shaped cross section). These piles are usually used for driving to bedrock. A steel pile can also be a pipe pile with a circular cross section. A pipe pile can be either an open-end pile or a closed-end pile, depending on whether the bottom end is open or closed.

Concrete piles, such as those shown in figure 1-10, may be either precast or cast in place. Most precast piles used today are pretensioned and are manufactured in established plants. These piles are made in square, cylindrical, or octagonal shapes. If they are being driven into soft or mucky soil, they are usually tapered. Cast-in-place piles are cast on the jobsite and are classified as shell type or shell-less type. The shell type is formed by driving a hollow steel tube (shell), with a closed end, into the ground and filling it with concrete. The shell-less type is formed by first driving a casing and core to the required depth. The core is removed and

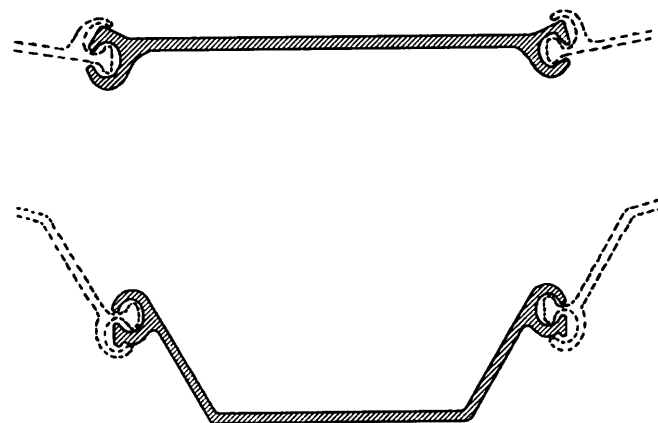


Figure 1-11.—Steel sheetpiling.

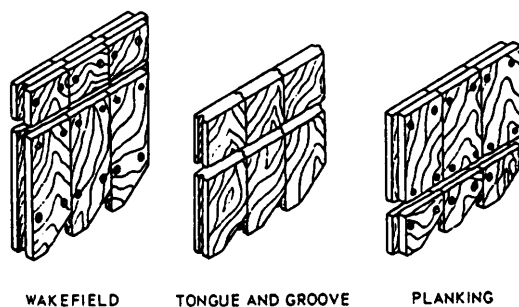


Figure 1-12.—Wood sheet piles.

the casing is filled with concrete. The casing is then removed, leaving the concrete in contact with the earth.

Sheet Piles

Sheet piles, made of wood, steel, or concrete, are equipped or constructed for edge-joining, so they can be driven edge-to-edge to form a continuous wall or bulkhead. A few common uses of sheet piles are as follows:

1. To resist lateral soil pressure as part of a temporary or permanent structure, such as a retaining wall
2. To construct cofferdams or structures built to exclude water from a construction area
3. To prevent slides and cave-ins in trenches or other excavations

The edges of steel sheetpiling are called **interlocks** (fig. 1-11) because they are shaped for locking the piles together edge-to-edge. The part of the pile between the interlocks is called the **web**.

A wood sheet pile might consist of a single, double, or triple layer of planks, as shown in figure 1-12. Concrete sheet piles are cast with tongue-and-groove edges for edge-joining.

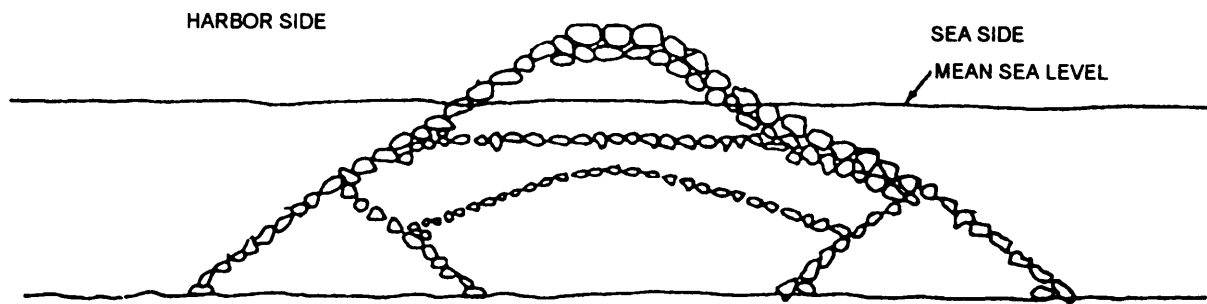


Figure 1-13.—Rubble-mound breakwater or jetty.

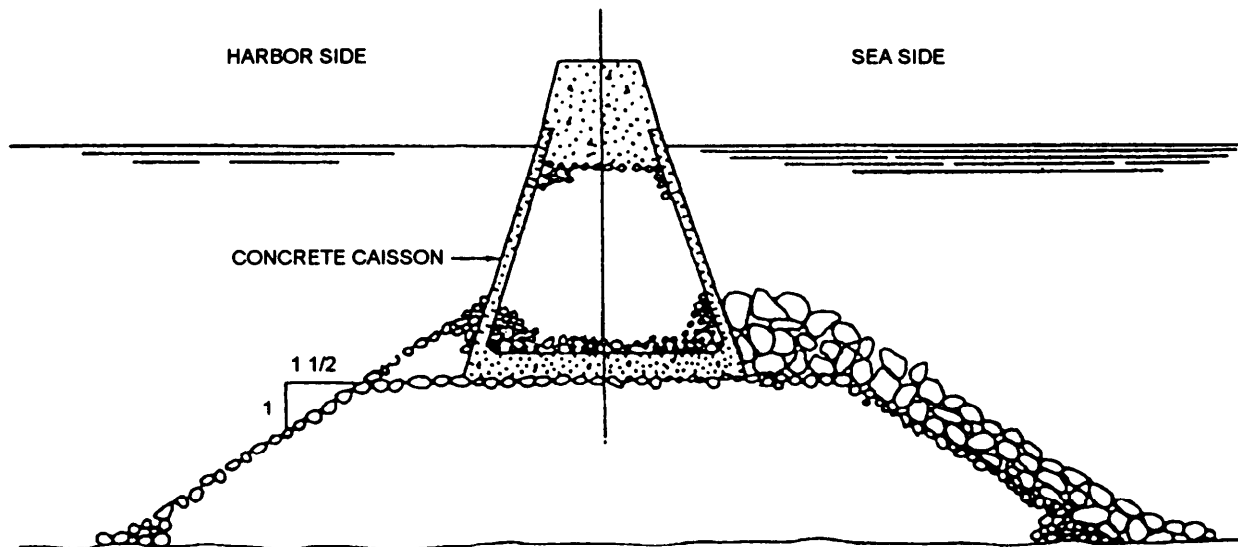


Figure 1-14.—Composite breakwater or jetty.

WATERFRONT STRUCTURES

Waterfront structures may be broadly divided into three types as follows: (1) harbor-shelter structures, (2) stable-shoreline structures, and (3) wharfage structures.

HARBOR-SHELTER STRUCTURES

Harbor-shelter structures are offshore structures that are designed to create a sheltered harbor. Various types of these structures are discussed below.

A **breakwater** is an offshore barrier, erected to break the action of the waves and thereby maintain an area of calm water inside the breakwater. A **jetty** is a similar structure, except that its main purpose is to direct the current or tidal flow along the line of a selected channel.

The simplest type of breakwater or jetty is the rubble-mound (also called rock-mound) type shown in figure 1-13. The width of its cap may vary from 15 to

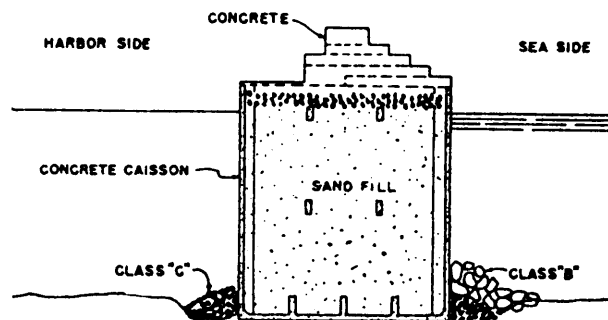


Figure 1-15.—Caisson breakwater or jetty.

70 feet. The width of its base depends on the width of the cap, height of the structure, and the slopes of the inner and outer faces. For a deepwater site or from with an extra-high tide range, a rubble-mound breakwater may be topped with a concrete cap structure, such as shown in figure 1-14. A structure of this type is called a composite breakwater or jetty. In figure 1-14, the cap structure is made of a series of precast concrete

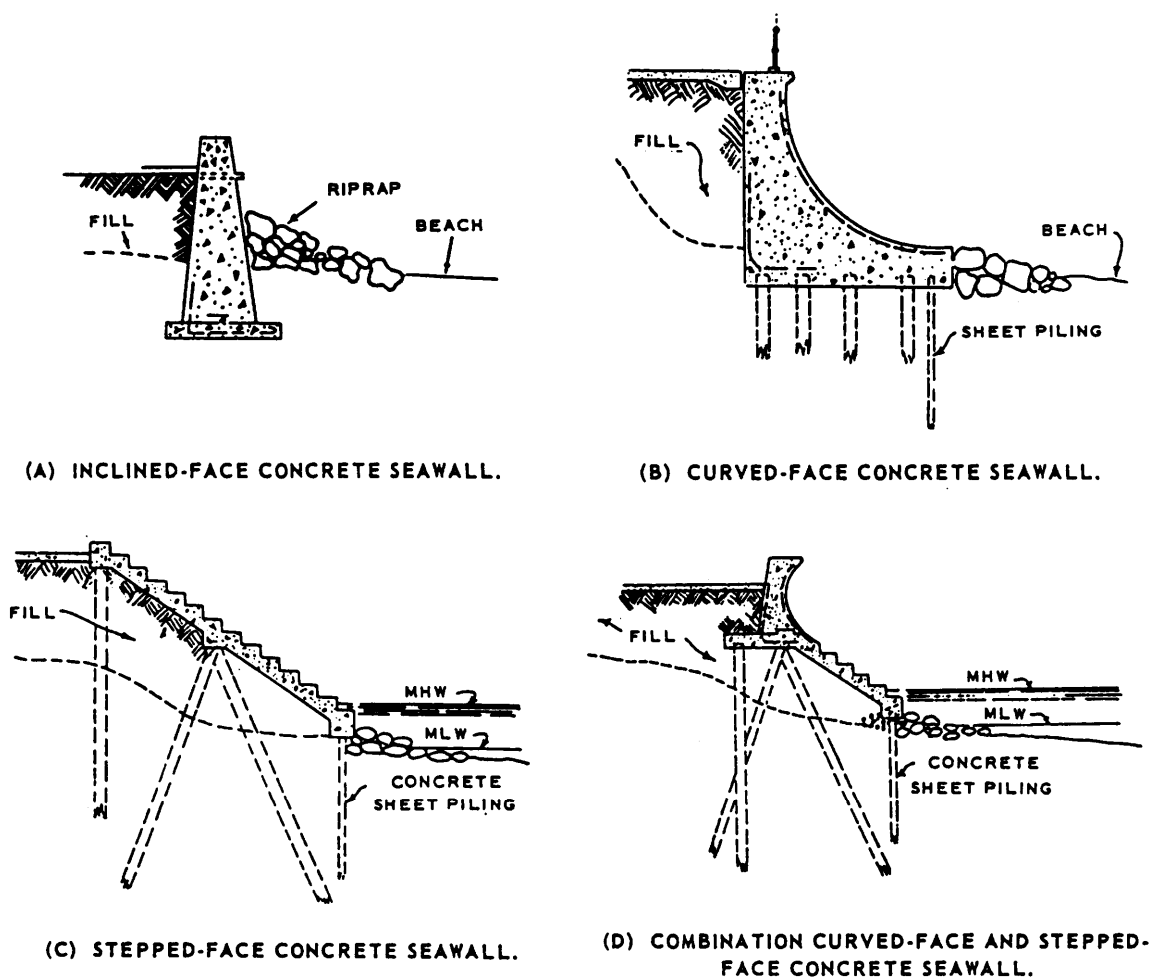


Figure 1-6.—Various types of seawalls.

boxes called **caissons**, each of which is floated over its place of location, and then sunk into position. A monolithic (single-piece) concrete cap is then cast along the tops of the caissons. Sometimes, breakwaters and jetties are built entirely of caissons, as shown in figure 1-15.

A **groin** is a structure similar to a breakwater or jetty, but it has a third purpose. A groin is used in a situation where a shoreline is subject to alongshore erosion, caused by wave or current action parallel or oblique to the shoreline. The groin is run out from the shoreline (usually there is a succession of groins at intervals) to check the alongshore wave action or deflect it away from the shore.

A **mole** is a breakwater that is paved on the top for use as a wharfage structure. To serve this purpose, it must have a vertical face on the inner side, or harborside. A jetty may be similarly constructed and used, but it is still called a jetty.

STABLE-SHORELINE STRUCTURES

These structures are constructed parallel with the shoreline to protect it from erosion or other wave damage.

A **seawall** is a vertical or sloping wall that offers protection to a section of the shoreline against erosion and slippage caused by tide and wave action. A seawall is usually a self-sufficient type of structure, such as a gravity-type retaining wall. Seawalls are classified according to the types of construction. A seawall may be made of riprap or solid concrete. Several types of seawall structures are shown in figure 1-16.

A **bulkhead** has the same general purpose as a seawall; namely, to establish and maintain a stable shoreline. However, while a seawall is self-contained, relatively thick, and is supported by its own weight, the bulkhead is a relatively thin wall. Bulkheads are classified according to types of construction, such as the following:

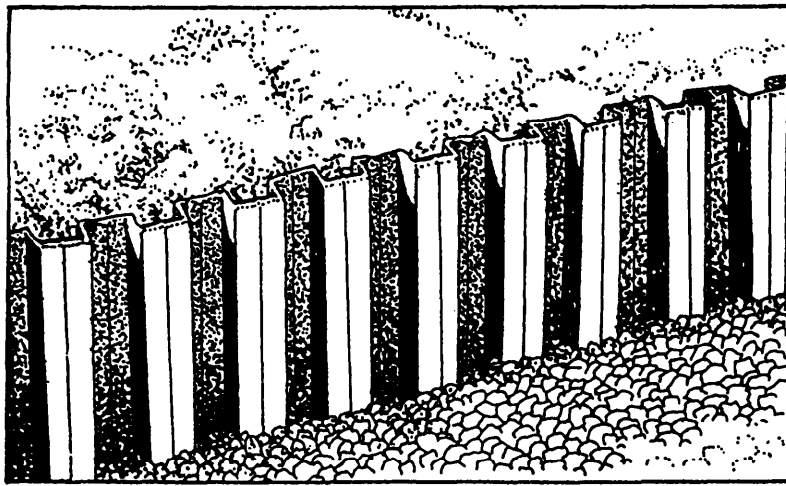


Figure 1-17.—Steel sheet-pile bulkhead.

1. Pile-and-sheathing bulkhead
2. Wood sheet-pile bulkhead
3. Steel sheet-pile bulkhead
4. Concrete sheet-pile bulkhead

Most bulkheads are made of steel sheet piles, such as shown in figure 1-17, and are supported by a series of tie wires or tie rods that are run back to a buried anchorage (or deadman). The outer ends of the tie rods are anchored to a steel wale that runs horizontally along the outer or inner face of the bulkhead. The wale is usually made up of pairs of structural steel channels that are bolted together back to back.

In stable soil above the groundwater level, the anchorage for a bulkhead may consist simply of a buried timber, a concrete deadman, or a row of driven and buried sheet piles. A more substantial anchorage for each tie rod is used below the groundwater level. Two common types of anchorages are shown in figure 1-18. In view A, the anchorage for each tie rod consists of a timber cap, supported by a batter pile, which is bolted to a bearing pile. In view B, the anchorage consists of a reinforced concrete cap, supported by a pair of batter piles. As shown in the figure, tie rods are supported by piles located midway between the anchorage and the bulkhead.

Bulkheads are constructed from working drawings like those shown in figure 1-19. The detail plan for the bulkhead shows that the anchorage consists of a row of sheet piles to which the inner ends of the tie rods are anchored by means of a channel wale.

The section view shows that the anchorage will lie 58 feet behind the bulkhead. This view also suggests the

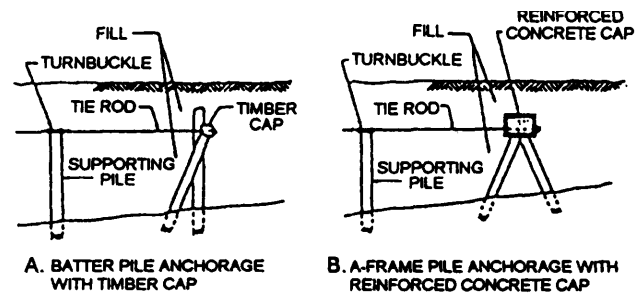


Figure 1-18.—Two types of tie-rod anchorages for bulkheads.

order of construction sequence. First, the shore and bottom will be excavated to the level of the long, sloping dotted line. The sheet piles for the bulkhead and anchorage will then be driven. The intervening dotted lines, at intervals of 19 feet 4 inches, represent supporting piles, which will be driven to hold up the tie rods. The piles will be driven next, and the tie rods then set in place. The wales will be bolted on, and the tie rods will be tightened moderately (they are equipped with turnbuckles for this purpose).

Backfilling to the bulkhead will then begin. The first backfilling operation will consist of filling over the anchorage, out to the sloping dotted line. The turnbuckles on the tie rods will then be set up to bring the bulkhead plumb. Then the remaining fill, out to the bulkhead, will be put in. Finally, outside the bulkhead, the bottom will be dredged to a depth of 30 feet.

To make it possible for ships to come alongside the bulkhead, it will be fitted with a timber cap and batter fender piles, as shown in figure 1-20. These piles, installed at proper intervals, will provide protection against the impact of ships and will protect the hulls of ships from undue abrasion.

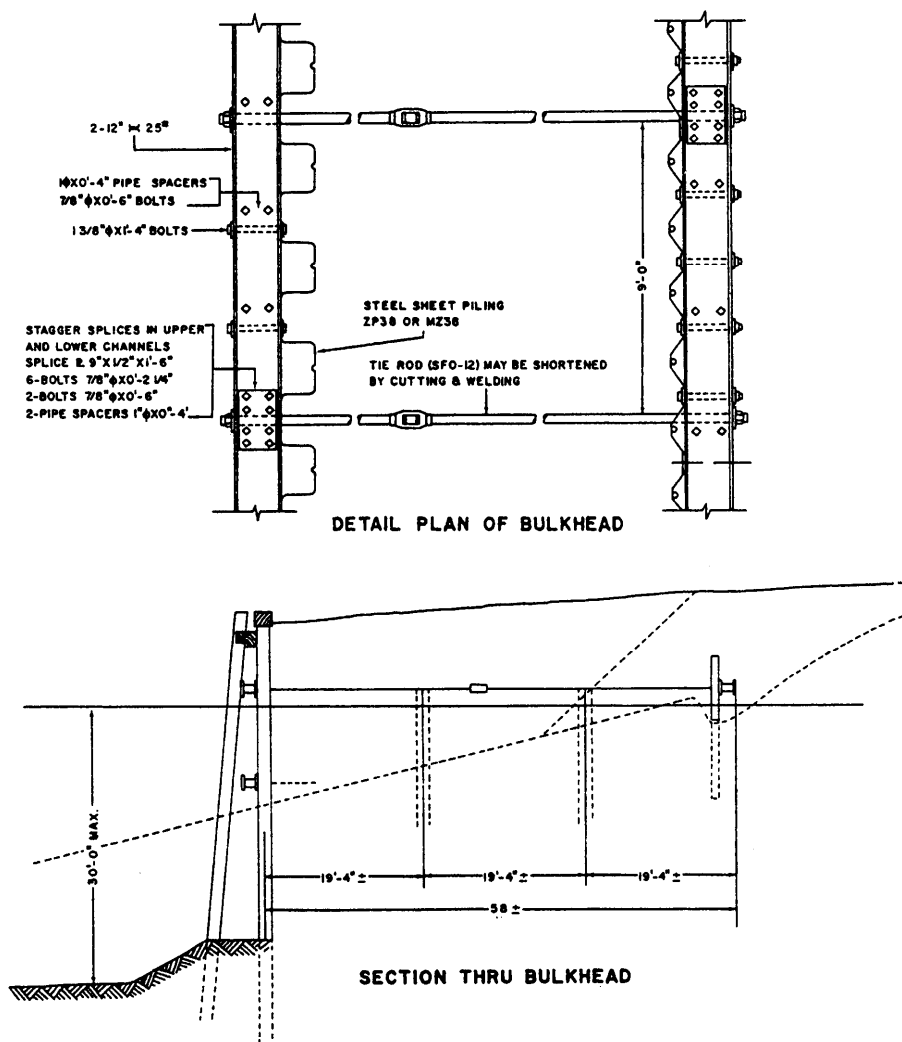


Figure 1-19.—Working drawings for steel sheet-pile bulkhead.

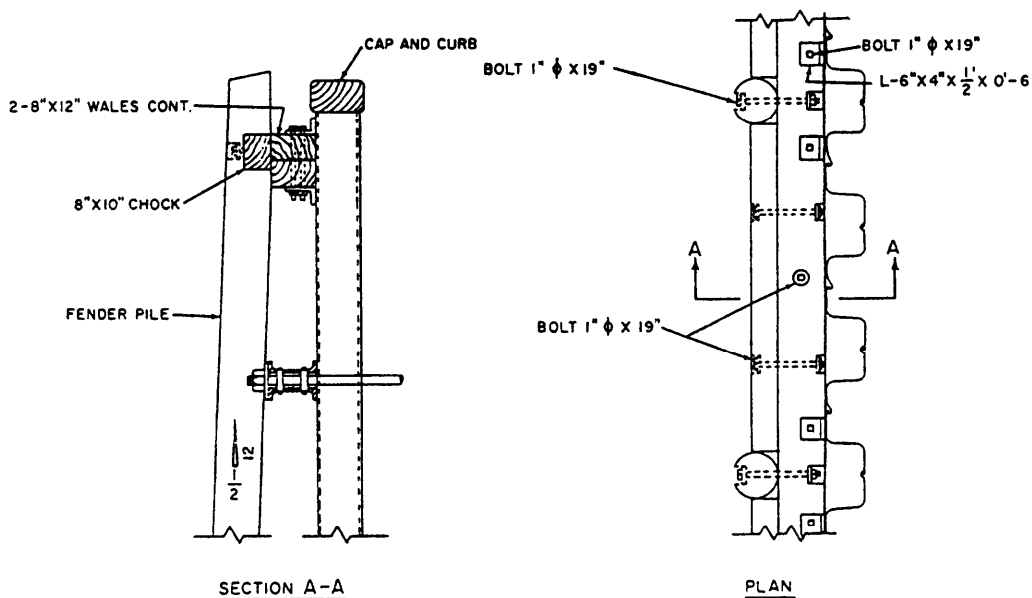


Figure 1-20.—Cap and fender pile for bulkhead.

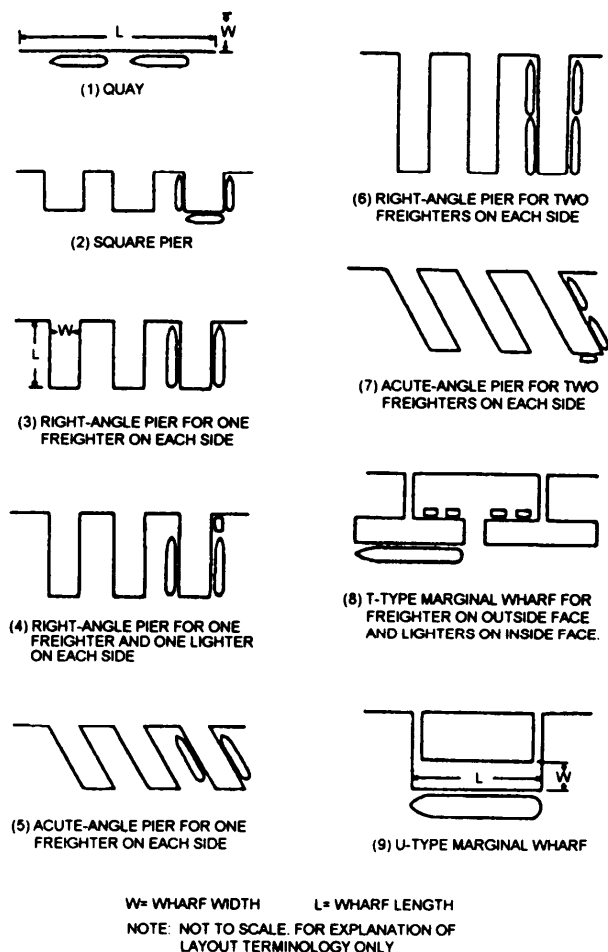


Figure 1-21.—Types of wharfage structures.

WHARFAGE STRUCTURES

Wharfage structures are designed to allow ships to lie alongside for loading and discharge. Figure 1-21 shows various plan views of wharfage structures. Any of these may be constructed of fill material, supported

by bulkheads. However, a pier or marginal wharf usually consists of a timber, steel, or concrete superstructure, supported on a substructure of timber, steel-, or concrete-pile bents.

Working drawings for advanced-base piers are contained in *Facilities Planning Guide*, Volume 1, NAVFAC P-437. Figures 1-22, 1-23, and 1-24 are portions of the advanced-base drawing for a 40-foot timber pier.

Each part of a pier lying between adjacent pile bents is called a bay, and the length of a single bay is equal to the on-center spacing of the bents. In the general plan shown in figure 1-22, you can see that the 40-foot pier consists of one 13-foot outboard bay, one 13-foot inboard bay, and as many 12-foot interior bays as needed to meet the length requirements for the pier.

The cross section shown in figure 1-24 shows that each bent consists of six bearing piles. The bearing piles are braced transversely by diagonal braces. Additional transverse bracing for each bent is provided by a pair of batter piles. The batter angle is specified as 5 in 12. One pile of each pair is driven on either side of the bent, as shown in the general plan. The butts of the batter piles are joined to 12-inch by 12-inch by 14-foot longitudinal batter-pile caps, each of which is bolted to the undersides of two adjacent bearing-pile caps in the positions shown in the part plan. The batter-pile caps are placed 3 feet inboard of the center lines of the outside bearing piles in the bent. They are backed by 6- by 14-inch batter-pile cap blocks, each of which is bolted to a bearing-pile cap. Longitudinal bracing between bents consists of 14-foot lengths of 3 by 10 planks, bolted to the bearing piles.

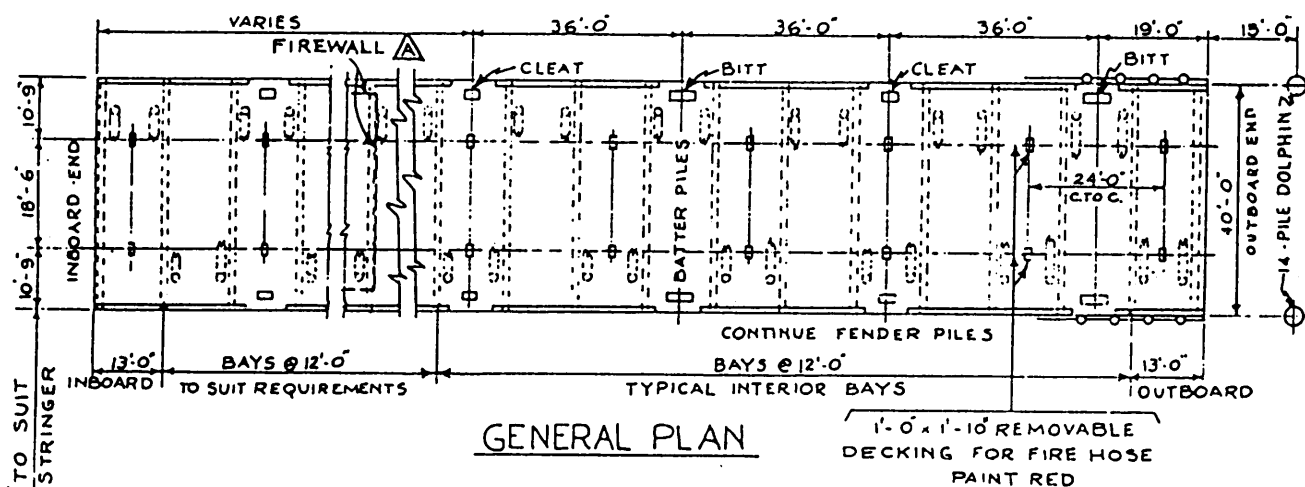


Figure 1-22.—General plan of an advanced-base 40-foot timber pier.

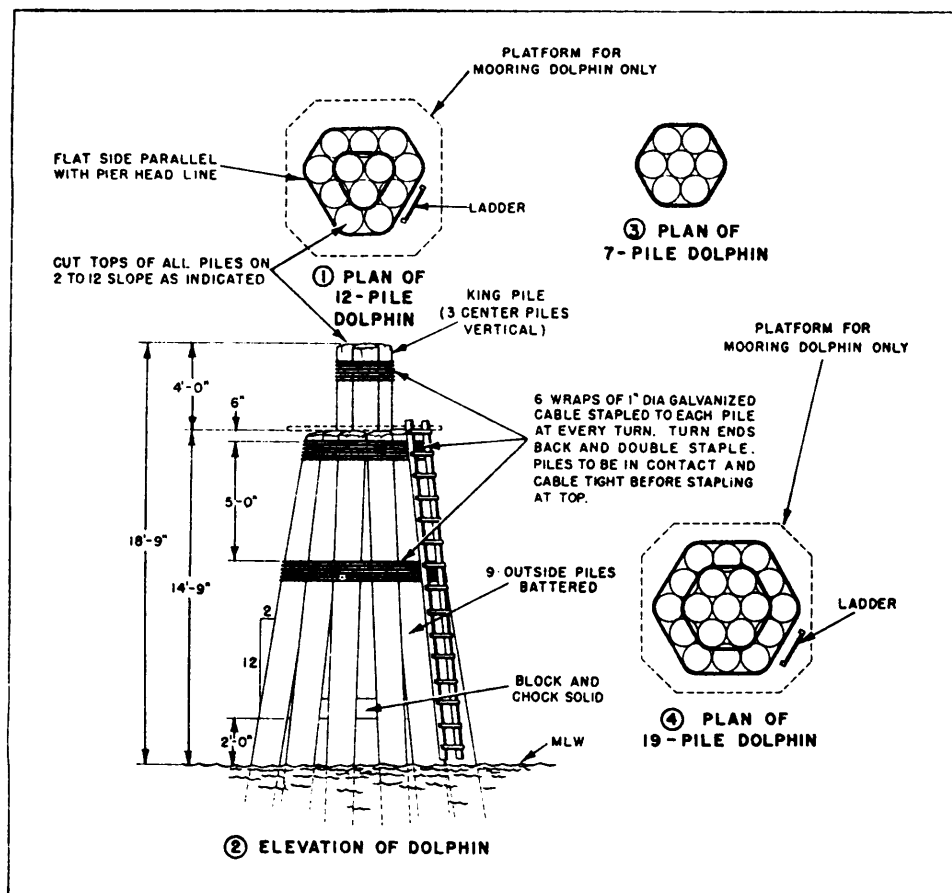


Figure 1-25.—Dolphins.

The superstructure (fig. 1-24) consists of a single layer of 4 by 12 planks laid on 19 inside stringers measuring 6 inches by 14 inches by 14 feet. The inside stringers are fastened to the pile caps with driftbolts. The outside stringers are fastened to the pile caps with bolts. The deck planks are fastened to the stringers with 3/8-by 8-inch spikes. After the deck is laid, 12-foot lengths of 8 by 10 are laid over the outside stringers to form the curbing. The lengths of curbing are distributed as shown in the general plan. The curbing is bolted to the outside stringers.

The pier is equipped with a fender system for protection against shock, caused by contact with vessels coming or lying alongside. Fender piles, spaced as shown in the part plan, are driven along both sides of the pier and bolted to the outside stringers. The heads of these bolts are countersunk below the surfaces of the piles. An 8-by-10 fender wale is bolted to the backs of the fender piles. Lengths of 8-by-10 fender-pile chocks are cut to fit between the piles and bolted to the outside stringers and the fender wales. The spacing for these bolts is shown in the part plan. As shown in the general plan, the fender system also includes two 14-pile

dolphins, located 15 feet beyond the end of the pier. A **dolphin** is an isolated cluster of piles, constructed as shown in figure 1-25. A similar cluster attached to a pier is called a **pile cluster**.

TIMBER FASTENERS AND CONNECTORS

From your studies of the EA3 TRAMAN, you should be aware that it is usually unnecessary to call out in working drawings the types of fasteners used for light frame construction. This is not the case, however, for heavy timber construction. As an EA preparing drawings for timber structures, you need to have a working knowledge of timber fasteners and connectors and the manner in which they are used. The following text discusses the more common types.

TIMBER FASTENERS

Bolts used to fasten heavy timbers usually come in 1/2-, 3/4-, and 1-inch diameters and have square heads and nuts. In use, the bolts are fitted with round steel

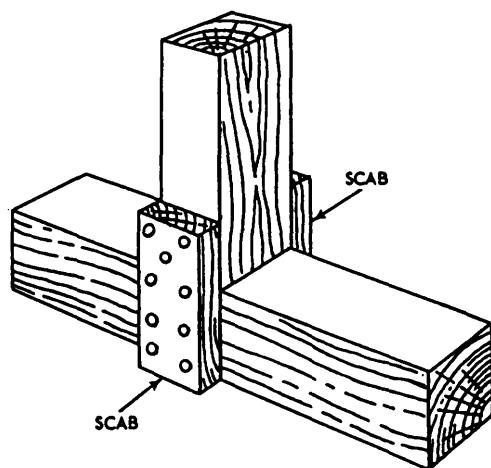


Figure 1-26.—Scabs.

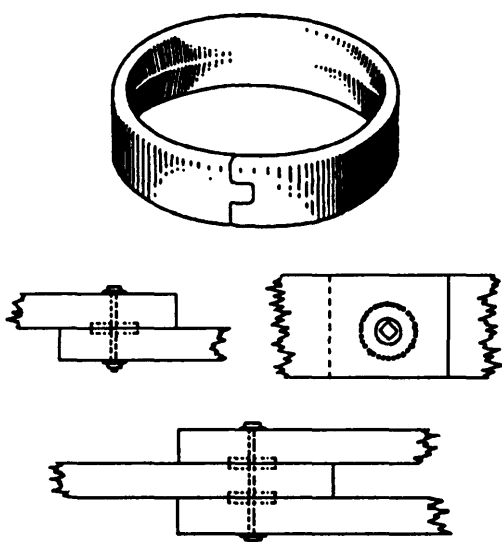
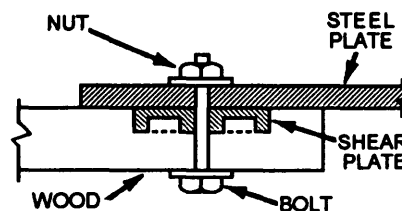
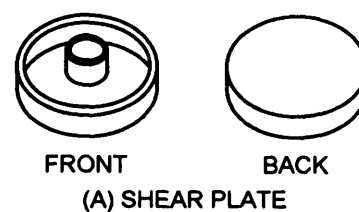


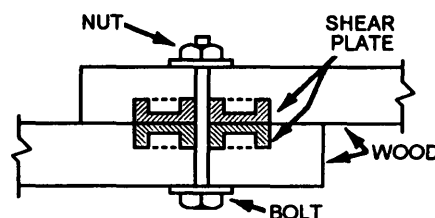
Figure 1-27.—Split ring and split-ring joints.

washers under both the bolt head and the nut. The bolts are then tightened until the washers bite well into the wood to compensate for future shrinkage. Bolts should be spaced a minimum of 9 inches on center and should be no closer than 2 1/2 inches to the edge or 7 inches to the end of the timber.

Driftbolts, also called **driftpins**, are used primarily to prevent timbers from moving laterally in relation to each other, rather than to resist pulling apart. They are used more in dock and trestle work than in trusses and building frames. A driftbolt is a long, threadless rod that is driven through a hole bored through the member and into the abutting member. The hole is bored slightly



(B) SHEAR PLATE CONNECTION
(WOOD-TO-STEEL)



(C) SHEAR PLATE CONNECTION
(WOOD-TO-WOOD)

Figure 1-28.—Shear plate and shear-plate joints.

smaller than the bolt diameter and about 3 inches shorter than the bolt length. Driftbolts are from 1/2 to 1 inch in diameter and 18 to 26 inches long.

Butt joints are customarily connected using driftbolts; however, another method of making butt-joint connections is to use a **scab**. A scab is a short length of timber that is spiked or bolted to the adjoining members, as shown in figure 1-26.

TIMBER CONNECTORS

A timber connector is any device used to increase the strength and rigidity of bolted lap joints between heavy timbers. For example, the **split ring** (fig. 1-27) is embedded in a circular groove. These grooves are cut with a special bit in the faces of the timbers that are to be joined. Split rings come in diameters of 2 1/2 and 4 inches. The 2 1/2-inch ring requires a 1/2-inch bolt, and the 4-inch ring uses a 3/4-inch bolt.

Shear plates are shown in figure 1-28. These connectors are intended for wood-to-steel connections, as shown in view B. But when used in pairs, they may

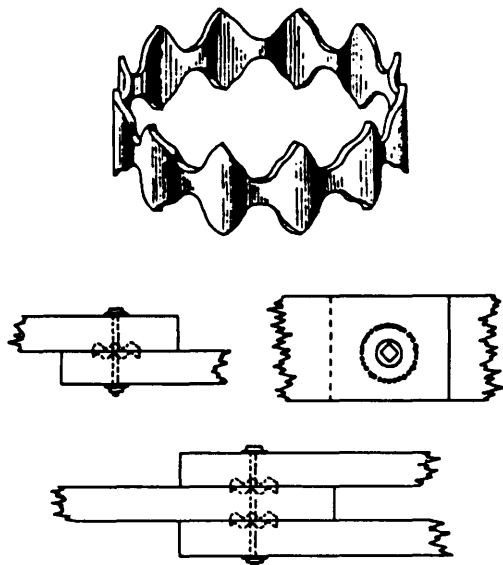


Figure 1-29.—Toothed ring and toothed-ring joints.

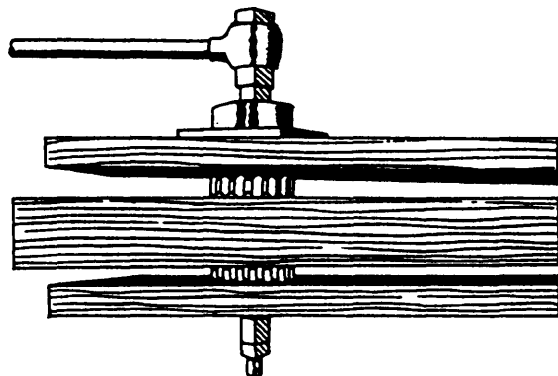


Figure 1-30.—Embedding toothed rings.

be used for wood-to-wood connections (view C). When making a wood-to-wood connection, the fabricator first cuts a depression into the face of each of the wood members. These depressions are cut to the same depth as the shear plates. Then a shear plate is set into each of the depressions so that the back face of the shear plate is flush with the face of the wood members. Finally, the wood members are slid into place and bolted together. Because the faces are flush, the members easily slide into position, which reduces the labor necessary to make the connection. Shear plates are available in 2 5/8- and 4-inch diameters.

For special applications, **toothed rings** and **spike grids** are sometimes used. The toothed ring connector

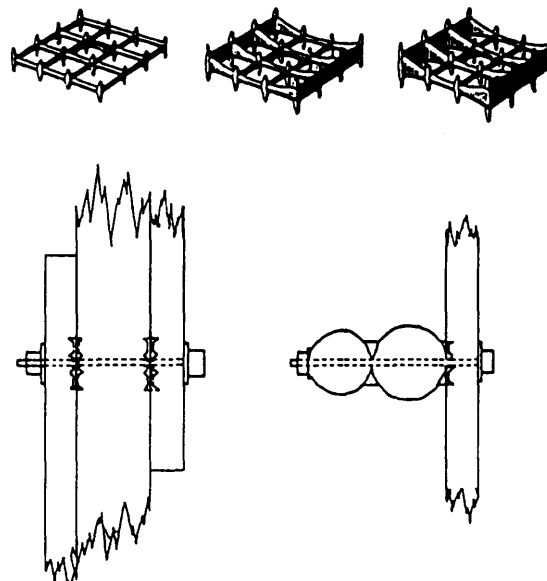


Figure 1-31.—Spike grids and spike-grid joints.

(fig. 1-29) functions in much the same manner as the split ring but can be embedded without the necessity of cutting grooves in the members. The toothed ring is embedded by the pressure provided from tightening a high-tensile strength bolt, as shown in figure 1-30. The hole for this bolt is drilled slightly larger than the bolt diameter so that the bolt may be extracted after the toothed ring is embedded. The spike grid is used as shown in figure 1-31. A spike grid may be flat (for joining flat surfaces), single-curved (for joining a flat and a curved surface), or double-curved (for joining two curved surfaces). A spike grid is embedded in the same manner as a toothed ring.

STRUCTURAL STEEL

Structural steel is one of the basic materials commonly used in structures, such as industrial and commercial buildings, bridges, and piers. It is produced in a wide range of shapes and grades, which permits great flexibility in its usage. It is relatively inexpensive to manufacture and is the strongest and most versatile material available to the construction industry. This













OLD SYMBOL	OLD ILLUSTRATED USE	DESCRIPTION	EXAMPLE	NEW SYMBOL	NEW ILLUSTRATED USE
WF	24 WF 76	W-SHAPE (WIDE FLANGE)		W	W24 X 76
BP	14 BP 73	BEARING PILE		HP	HP14 X 73
I	15 I 42.9	S-SHAPE (AMERICAN STD I-BEAM)		S	S15 X 42.9
C	9 C 13.4	C-SHAPE (AMERICAN STD CHANNEL)		C	C9 X 13.4
M	8 X 8 M 34.3	M-SHAPE (MISC SHAPES OTHER THAN W, BP, S, & C)		M	M8 X 34.3
M	8 M 17				M8 X 17
Jr	7 Jr 5.5				M7 X 5.5
C	12 X 4 C 44.5	MC-SHAPE (CHANNELS OTHER THAN AMERICAN STD)		MC	MC12 X 45
Jr C	10 Jr C 84				MC12 X 12.6
L	L3 X 3 X 1/4	ANGLES : EQUAL LEG		L	L3 X 3 X 1/4
L	L7 X 4 X 1/2	UN-EQUAL LEG		L	L7 X 4 X 1/2
ST	ST5 WF 10.5	TEES, STRUCTURAL : CUT FROM W-SHAPE CUT FROM S-SHAPE CUT FROM M-SHAPE		WT	WT12 X 38
				ST	ST12 X 38
				MT	MT12 X 38
PL	PL 18 X 1/2 X 2'-6"	PLATE		PL	PL 1/2 X 18" X 30"
BAR	BAR 2 1/2 X 1/4	FLAT BAR		BAR	BAR 2 1/2 X 1/4
O	O 6	PIPE, STRUCTURAL			PIPE 4 STD PIPE 4X-STRG PIPE 4 XX-STRG

Figure 1-32.—Structural steel shapes and designations.

section describes structural steel shapes, the terminology applied to structural steel members, the use of these members, and the methods by which they are connected.

STRUCTURAL STEEL SHAPES

Structural steel is manufactured in a wide variety of cross-sectional shapes and sizes. Figure 1-32 shows many of these various shapes.

Figure 1-33 shows cross-sectional views of the **W-shape** (wide flange), the **S-shape** (American Standard I-beam), and the **C-shape** (American Standard channel). The W-shape is the most widely used structural member for beams, columns, and other load-bearing applications. As seen in the figure, it has parallel inner and outer flange surfaces that are of constant thickness. This flange design provides greater cross-sectional area in the flanges, which results in greater strength than is provided by the S-shape, which has a slope of approximately 17 degrees on the inner flange surfaces. The C-shape is similar to the S-shape in that its inner flange surface is also sloped approximately 17 degrees. The C-shape is especially useful in locations

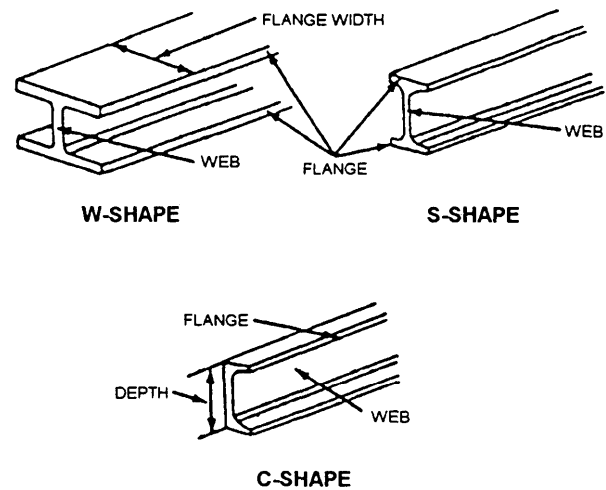


Figure 1-33.—Structural shapes.

where a single flat surface on one side is required. When used alone, the C-shape is not very efficient as a beam or column. However, efficient built-up members may be constructed of channels assembled together with other structural shapes and connected by rivets or welds.

The W-, S-, and C-shape structural members are designated by their nominal depth, in inches, along the

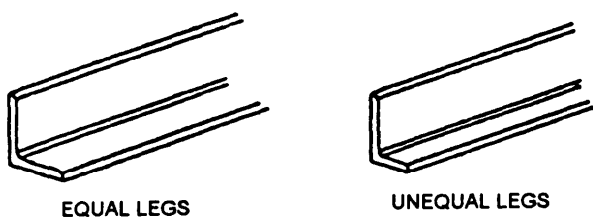


Figure 1-34.—Angles.

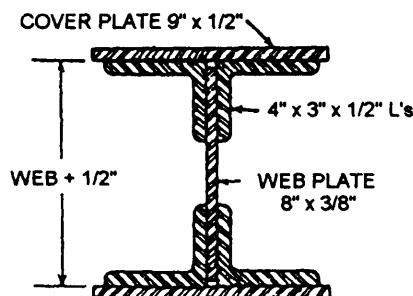


Figure 1-35.—Built-up column section.

web and the weight, in pounds, per foot of length. A W14 x 30, for example, indicates a W-shape that is 14 inches deep along its web and weighs 30 pounds per linear foot. Hence a 20-foot length of this size W-shape would weigh a total of 600 pounds.

The **bearing pile**, HP-shape, is almost identical to the W-shape. The only difference is the thickness of the web and flange. In the bearing pile, the web and flange thickness are equal, whereas the W-shape has unequal web and flange thickness.

An **angle** is a structural shape whose cross section resembles the letter *L*. As pictured in figure 1-34, angles are available with either equal or unequal legs. The dimension and thickness of its legs are used to identify an angle; for example, L6 x 4 x 1/2. The dimension of each leg is measured along the outside of the angle, and for unequal-leg angles, the dimension of the wider leg is always given first, as in the example just cited. The third dimension applies to the thickness of the legs, which always have equal thickness. Angles are used primarily to support, brace, or connect other structural members. They may be used as single members, or they may be used in combinations of two or four to form main members.

Steel **plate** is a structural member that has a width greater than 8 inches and a thickness of 1/4 inch or more. Plates are generally used as connections between other structural members. They may also be used as

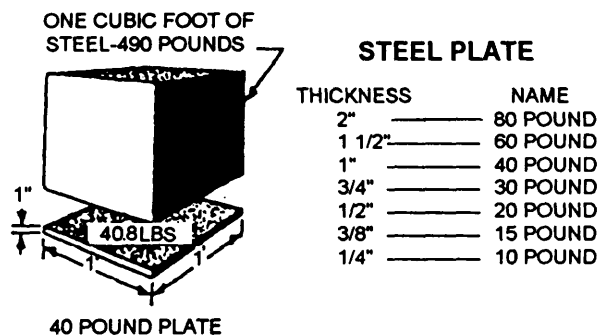


Figure 1-36.—Weight and thickness of steel plate.

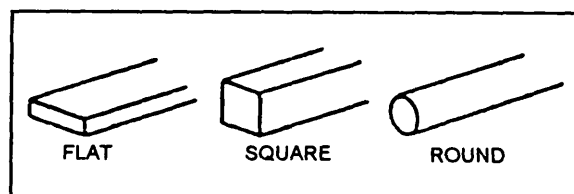


Figure 1-37.—Bars.

component parts of built-up structural members, such as the built-up column shown in figure 1-35. Plates cut to specific sizes may be obtained in widths ranging from 8 inches to 120 inches or more and in various thicknesses.

Plates are identified by their thickness, width, and length, all measured in inches; for example, PL 1/2 x 18 x 30. Sometimes, you may also hear plate referred to by its approximate weight per square foot for a specified thickness. As shown in figure 1-36, 1 cubic foot of steel weighs 490 pounds. This weight divided by 12 gives you 40.8 pounds, which is the weight of a steel plate measuring 1 foot square and 1 inch thick. By dropping the fractional portion, a 1-inch plate is called a 40-pound plate; and, with similar reasoning, a 1/2-inch plate is called a 20-pound plate.

The structural shape referred to a **bar** has a width of 8 inches or less and a thickness greater than 3/16 inch. The edges of bars usually are rolled square, like universal mill plates. The dimensions are expressed in a similar manner as that for plates; for instance, bar 6 x 1/2. Bars are available in a variety of cross-sectional shapes—round, hexagonal, octagonal, square, and flat. Three different shapes are shown in figure 1-37. Both squares and rounds are commonly used as bracing members of light structures. Their dimensions, in

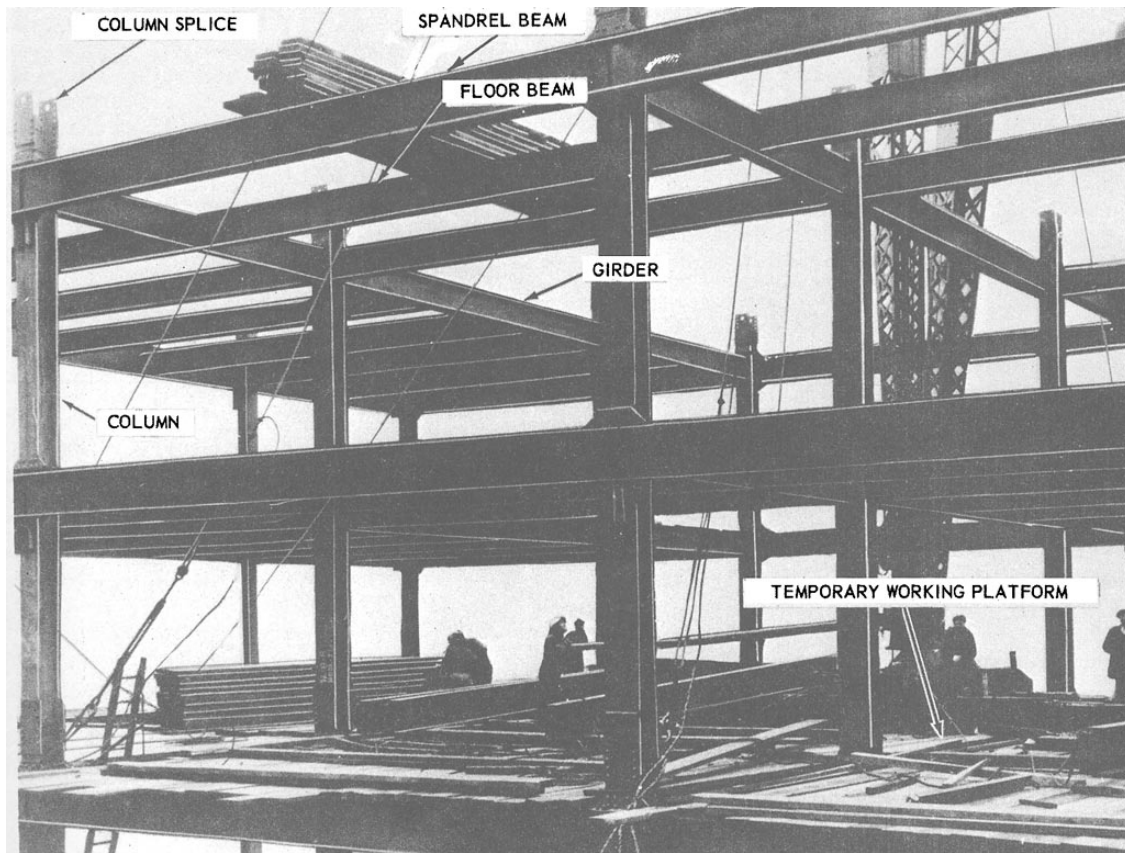


Figure 1-38.—Structural steel skeleton construction.

inches, apply to the side of the square or the diameter of the round.

STEEL FRAME STRUCTURES

The construction of a framework of structural steel involves two principal operations: fabrication and erection. Fabrication involves the processing of raw materials to form the finished members of the structure. Erection includes all rigging, hoisting, or lifting of members to their proper places in the structure and making the finished connections between members.

A wide variety of structures are erected using structural steel. Basically, they can be listed as buildings, bridges, and towers; most other structures are modifications of these three.

Buildings

There are three basic types of steel construction. These may be designated as **wall-bearing**

construction, skeleton construction, and long-span construction.

In wall-bearing construction, exterior and interior masonry walls are used to support structural members, such as steel beams and joists, which carry the floors and roof. It should be noted that while this section of your TRAMAN discusses steel structures, wall-bearing construction is applicable to nonsteel structures as well. Wall-bearing construction is one of the oldest and most common methods in use. Although modern developments in reinforced concrete masonry make the use of this method feasible for high-rise structures, wall-bearing construction is normally restricted to relatively low structures, such as residences and light industrial buildings.

A tall building with a steel frame, such as shown in figure 1-38, is an example of skeleton construction. In this type of construction, all live and dead loads are carried by the structural-frame skeleton. For this reason, the exterior walls are nonbearing **curtain walls**. Roof and floor loads are transmitted to beams and girders,

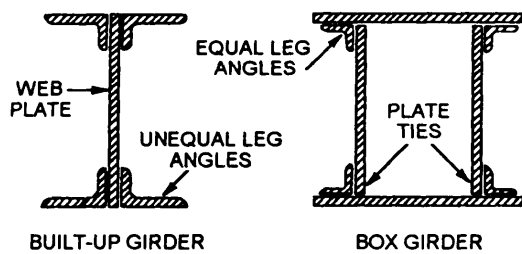


Figure 1-39.—Typical built-up girders.

which are, in turn, supported by columns. The horizontal members or beams that connect the exterior columns are called **spandrel beams**. If you add additional rows of columns and beams, there is no limitation to the area of floor and roof that can be supported using skeleton construction. One limitation on using skeleton construction, however, is the distance between columns.

Oftentimes, large structures, such as aircraft hangars, may require greater distances between supports than can be spanned by the standard structural steel shapes. In this case, one of several methods of long-span steel construction is used. One method uses built-up girders to span the distances between supports. Two types of built-up girders are shown in figure 1-39. As seen in this figure, the built-up girder consists of steel plates and shapes that are combined together to meet the necessary strength. The individual parts of these girders are connected by welding or riveting.

Another method, which is usually more economical, is to use a **truss** to span large distances. As you learned in the EA3 TRAMAN, a truss is a framework of structural members consisting of a top chord, bottom chord, and diagonal web members that are usually placed in a triangular arrangement. (See figs. 1-40 and 1-41.) As shown in figure 1-40, trusses can be fabricated to conform to the shape of nearly any roof system.

A third long-span method, although not as versatile as trusses, is the use of **bar joists**. Bar joists are much lighter than trusses and are fabricated in several different types. One type is shown in figure 1-42. Prefabricated bar joists, designed to conform to specific load requirements, are obtainable from commercial companies. Other long-span construction methods involve several different types of framing systems, which include steel arches, cable-hung frames, and other types of systems. These methods are beyond the scope of this TRAMAN.

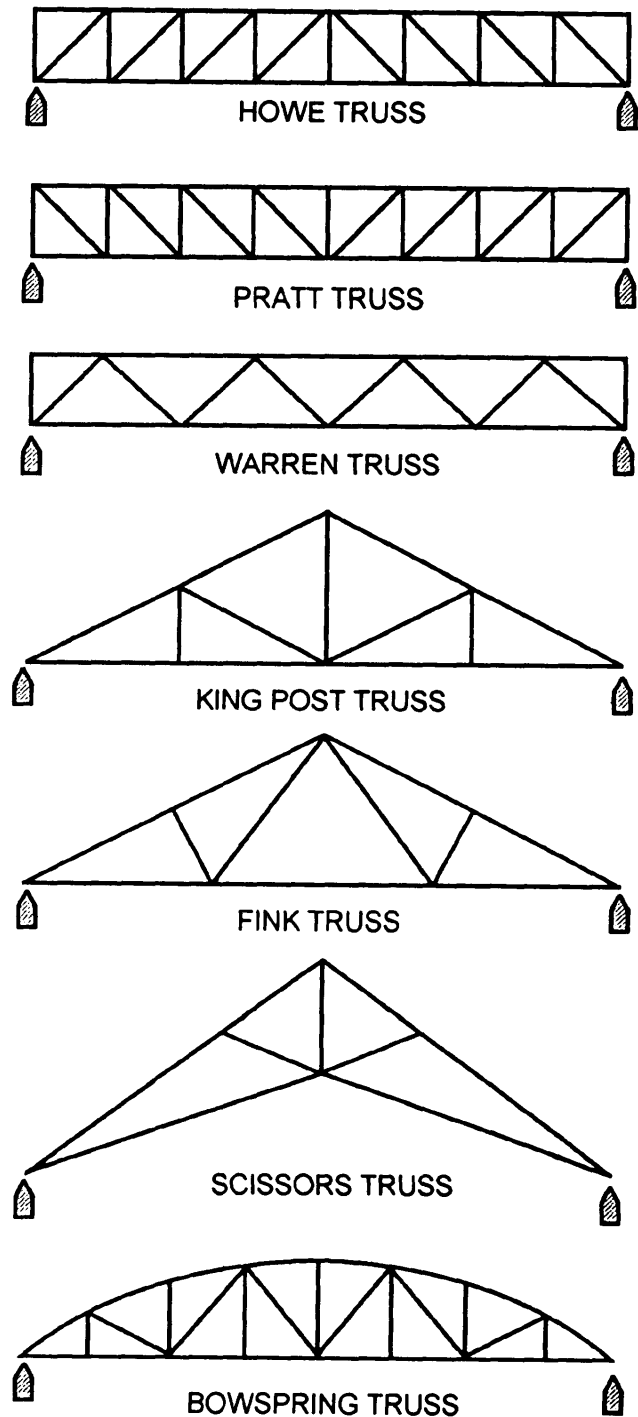


Figure 1-40.—Typical steel trusses.

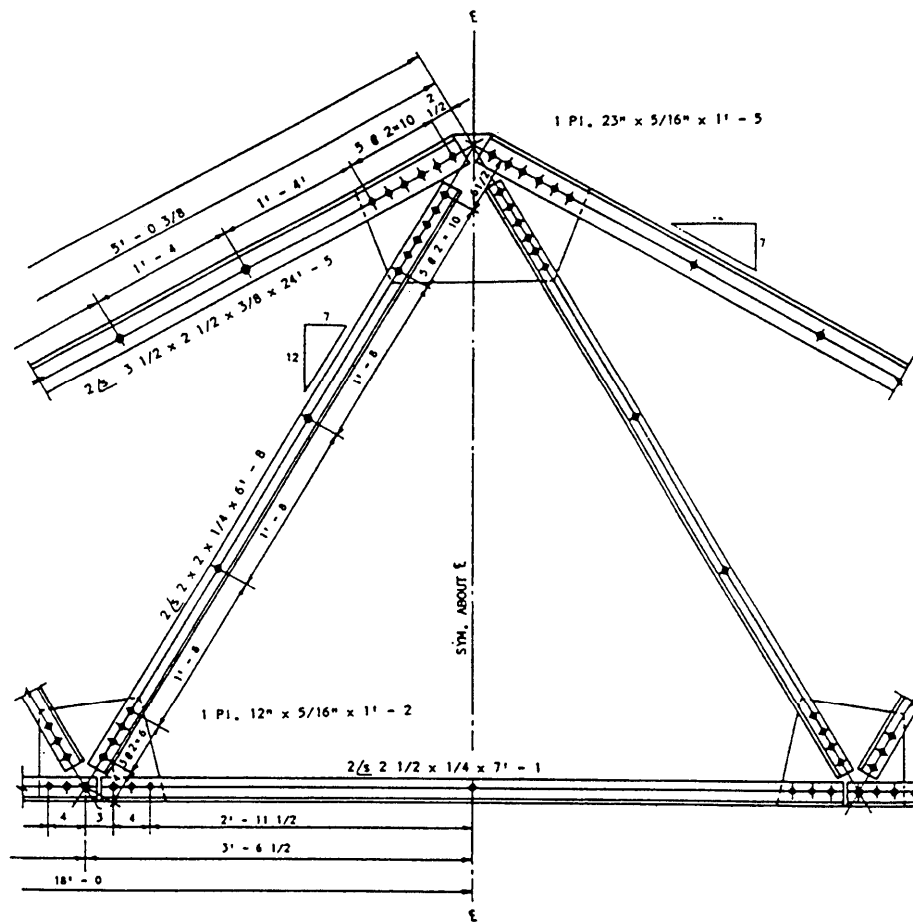


Figure 1-41.—Steel truss fabricated from angle-shaped members.

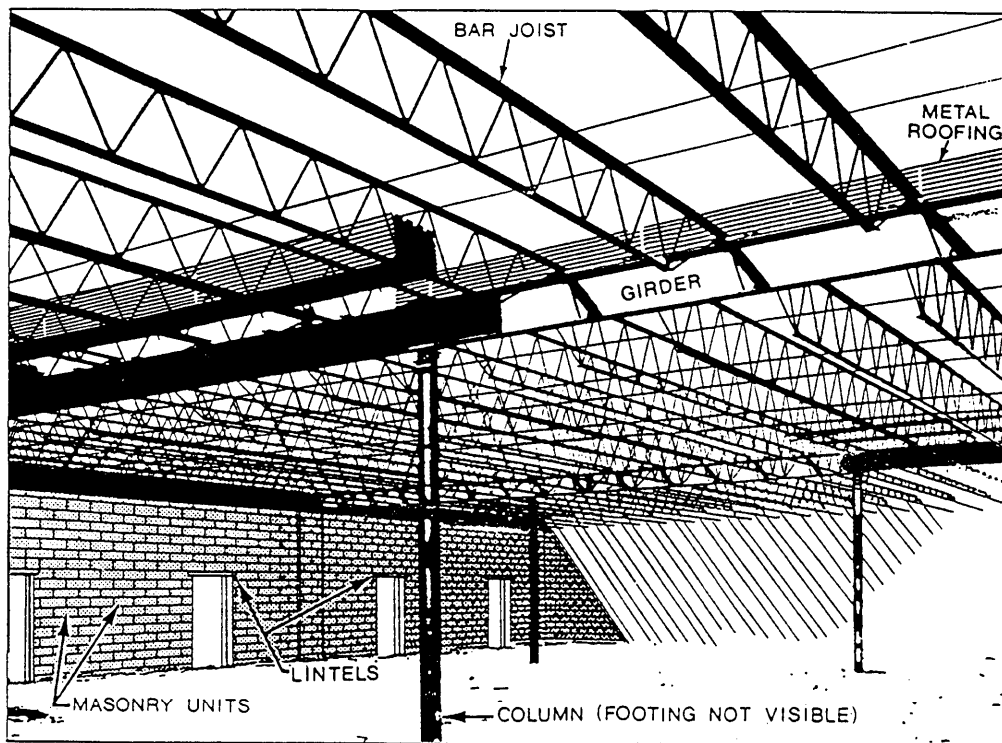


Figure 1-42.—Clear span bar joists.

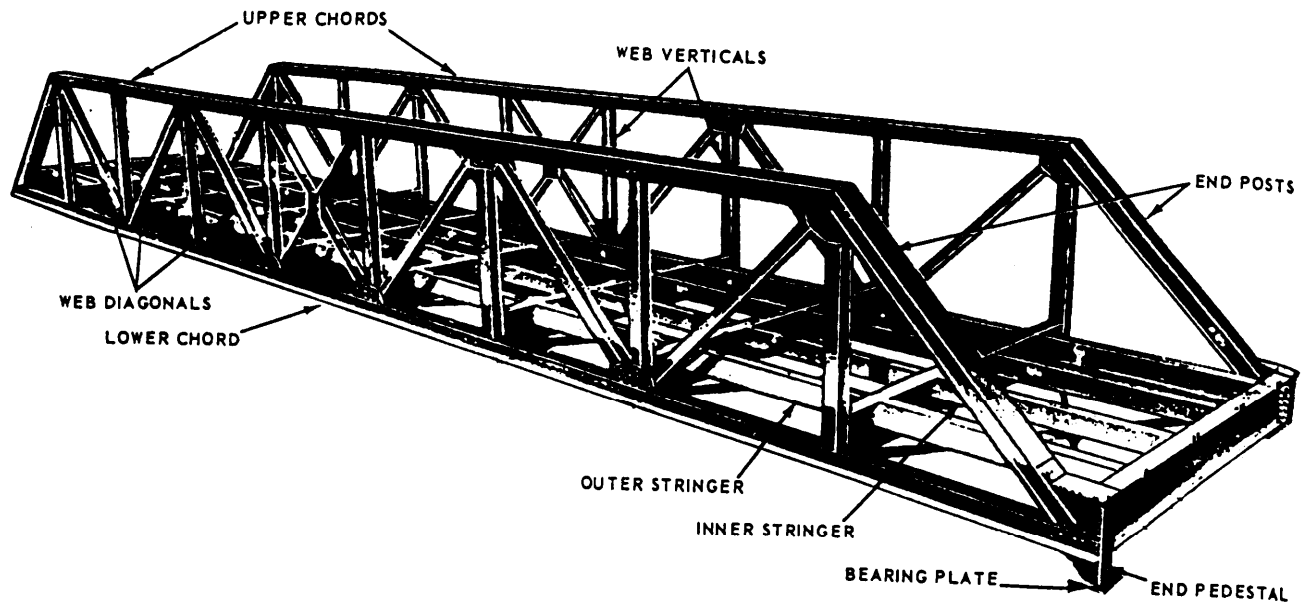


Figure 1-43.—Truss bridge.

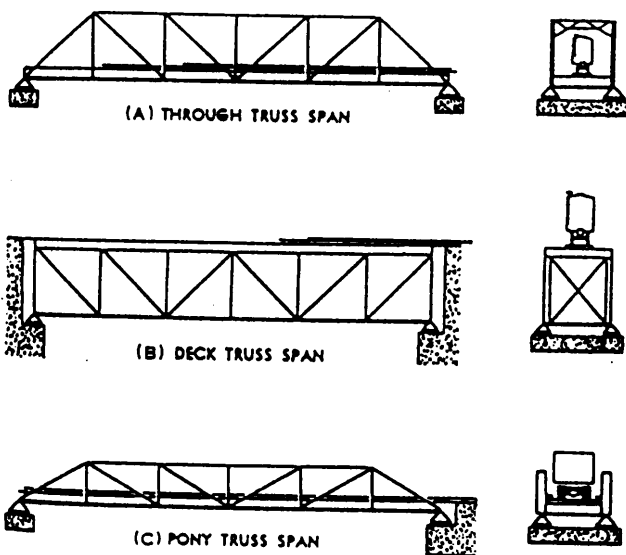


Figure 1-44.—Types of bridge spans.

Bridges

Figure 1-43 shows the structural framework of a single-span truss bridge. As with all bridges, the floor and traffic loads of the truss bridge are carried by the stringers. In the truss bridge, however, the stringers are supported by transverse beams rather than by the bridge abutments (and intermediate supports when needed). As seen in the figure, these transverse beams are supported by the structural framework of the two trusses. Finally, the entire bridge structure plus any traffic loads are transmitted through the **end pedestals** and **bearing plates** to the supporting abutments. As you will note, the nomenclature of the truss members is the same as discussed in the preceding section; however, the

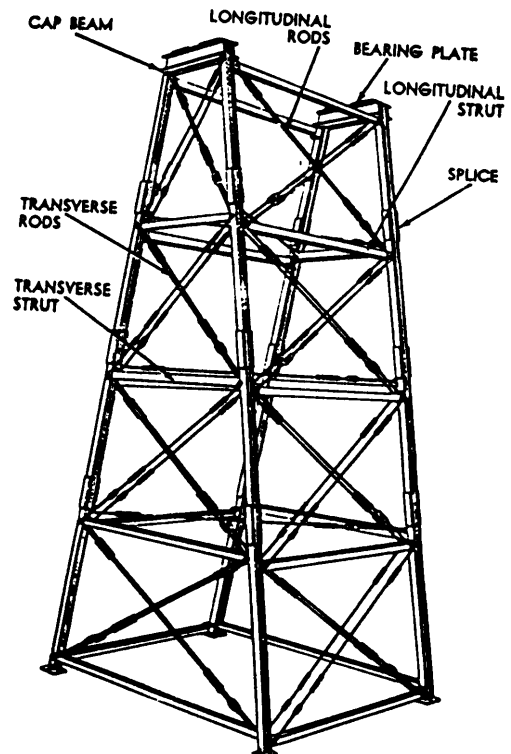


Figure 1-45.—A trestle tower.

diagonal end members, adjacent to the abutments, are normally called **end posts**.

The truss framework and the manner in which the trusses are used may differ depending upon the design of the truss bridge. Figure 1-44 shows three examples. View A shows a **through truss** span. In it, the traverse beams are connected to the bottom chord of the trusses, and the top chords are braced by a lateral bracing system under which traffic passes. In the **deck truss** span, view B, the traverse beams are carried by the top chord

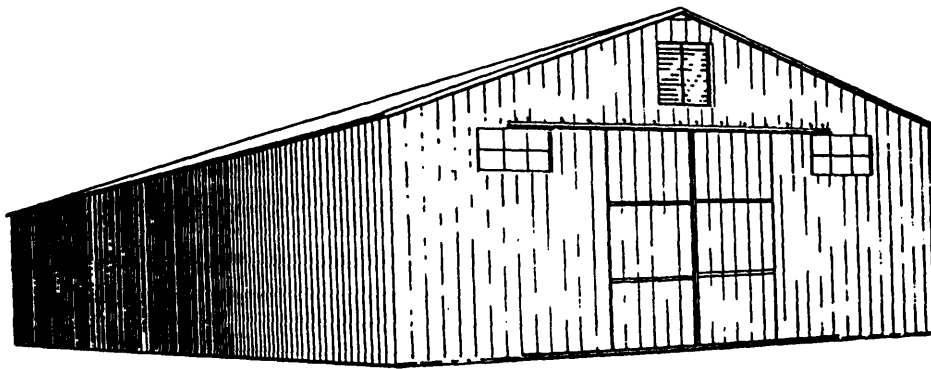


Figure 1-46.—Completed 40' x 100' x 14' preengineered metal building.

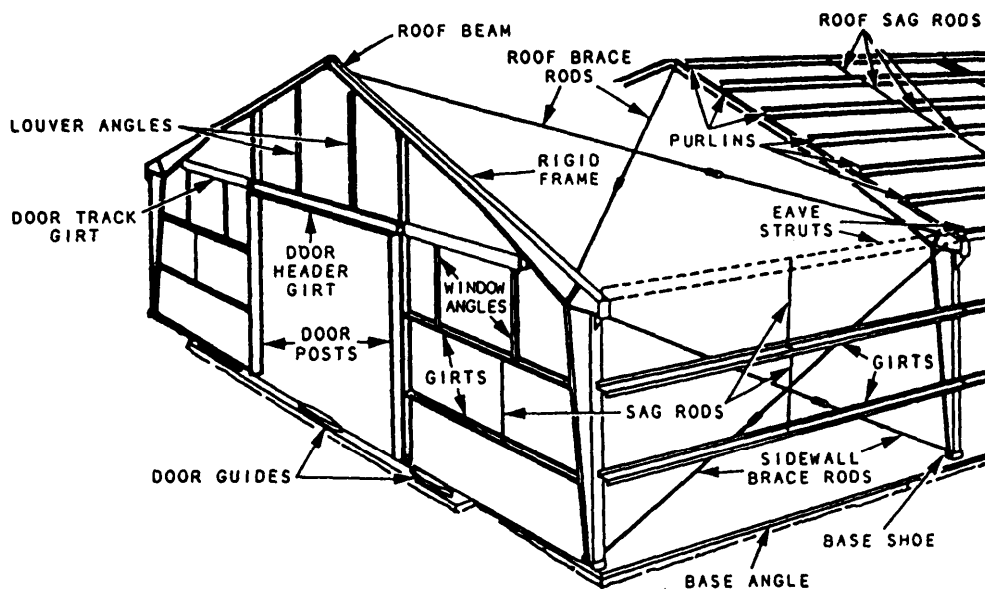


Figure 1-47.—Structural members of a preengineered metal building.

Again, a lateral bracing system is used between the trusses. The **pony truss** span is the same as that discussed in the preceding paragraph. Because of the small depth of the trusses, no top lateral bracing is used.

Towers

Towers are framework structures designed to provide vertical support. They may be used to support another structure, such as a bridge, or they may be used to support a piece of equipment, such as a communication antenna. Since the prime purpose of a tower is to provide vertical support for a load applied at the top, the compression members providing this support are the only ones that require high-structural strength. The rest of the structure is designed to stiffen the vertical members and to prevent bending under load. Primarily, the bracing members are designed to take loads in tension and are based on a series of diagonals. A typical trestle tower used in bridge construction is shown in figure 1-45.

Preengineered Metal Structures

Preengineered metal structures are commonly used in military construction. These structures are usually designed and fabricated by civilian industry to conform with specifications set forth by the military. Rigid frame buildings, steel towers, communications antennas, and steel tanks are some of the most commonly used structures, particularly at overseas advanced bases. Preengineered structures offer an advantage in that they are factory built and designed to be erected in the shortest amount of time possible. Each structure is shipped as a complete kit, including all the materials and instructions needed to erect it.

Of the preengineered metal structures available, the one that is perhaps most familiar to the Seabees is the preengineered metal building (PEB) shown in figures 1-46 and 1-47. Figure 1-47 shows the nomenclature of the various parts of the PEB. For definition of this nomenclature, erection details, and other important

information regarding the PEB, you should refer to the current *Steelworker* TRAMAN.

STRUCTURAL STEEL CONNECTORS

There are four basic connectors used in making structural steel connections. They are **bolts**, **welds**, **pins**, and **rivets**. Bolts and welds are the most common connectors used in military construction. Pins are used for connections at the ends of bracing rods and various support members that require freedom of rotation. Commercial prefabricated steel assemblies may be received in the field with riveted connectors. Types and uses of the four basic connectors are discussed in the following text.

Bolts

Bolts are used more than any other type of connectors. They are easy to use and, in contrast to all other types of connectors, require little special equipment. The development of higher strength steels and improved manufacturing processes have resulted in the production of bolts that will produce strong structural steel connections.

Specifications for most bolted structural joints call for the use of high-strength steel bolts tightened to a high tension. The bolts are used in holes slightly larger than the nominal bolt size. Joints that are required to resist shear between connected parts are designated as either **friction-type** or **bearing-type** connectors.

Bolted parts should fit solidly together when they are assembled and should NOT be separated by gaskets or any other type of compressible material. Holes should be a nominal diameter, not more than 1/16 inch in excess of the nominal bolt diameter. When the bolted parts are assembled, all joint surfaces should be free of scale, burrs, dirt, and other foreign material. Contact surfaces with friction-type joints must be free of oil, paint, or other coatings.

Welds

Welding is a highly specialized skill, and welding of load-bearing parts of a structure should be performed only by properly qualified personnel. As an EA, you will not be expected to perform welding operations.

However, you should have a general knowledge of the principal welding processes and the different types of welds and their applications, and you should know how welding symbols are used to identify welded connections shown in working drawings.

The two principal welding processes used in structural work are **electric arc** welding and **oxy-MAPP** gas welding. In the electric arc welding process, welding heat, sufficient to fuse the metal together, is developed by an electric arc formed between a suitable **electrode** (welding rod) and the **base metal** (the metal of the parts being welded). In the oxy-MAPP gas welding process, heat is obtained by burning a mixture of MAPP gas and oxygen as it is discharged from a torch designed for this purpose. While electric arc welding is normally used for metals that are 1/8 inch or larger in thickness, oxy-MAPP gas welding is usually restricted to thinner metals.

The principal types of welds and welded joints that are suitable for structural work are shown in figures 1-48 and 1-49.

On drawings, special symbols are used to show the kinds of welds to be used for welded connections. These symbols have been standardized by the American Welding Society (AWS). You should become familiar with the basic welding symbols and with the standard location of all elements of a welding symbol.

The distinction between a **weld symbol** and a welding symbol should be noted. A weld symbol is a basic symbol used to indicate the type of weld. Basic weld symbols are shown at the top of figure 1-50. The supplementary symbols shown in the figure are used when necessary in connection with the basic weld symbols.

A **welding symbol** consists of the following eight elements, or as many of these elements as are required: (1) reference line, (2) arrow, (3) basic weld symbol, (4) dimensions and other data, (5) supplementary symbols, (6) finish symbols, (7) tail, and (8) specification, process, or other reference. These elements of the welding symbol have specific standard locations with respect to each other, as shown in figure 1-50. When a finish symbol is used in a welding symbol, it indicates the method of finish, not the degree of finish. For example, a *C* is used to indicate finish by chipping, an *M* indicates machining, and a *G* indicates grinding.

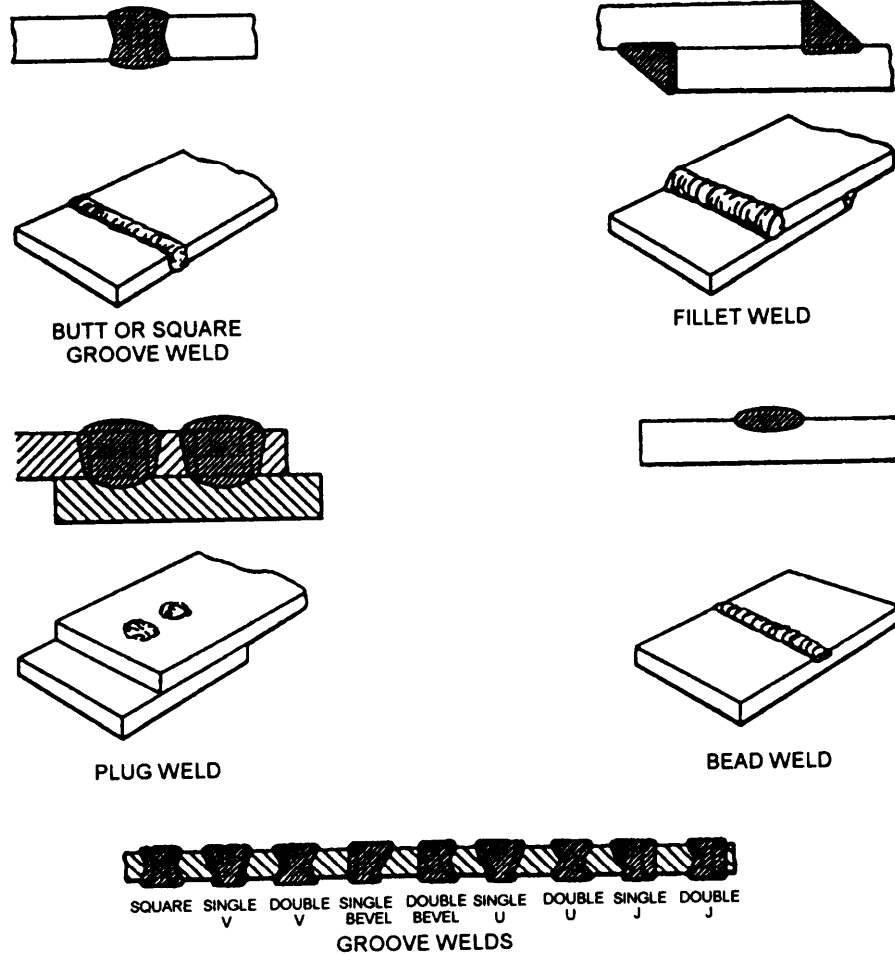


Figure 1-48.—Types of welds.

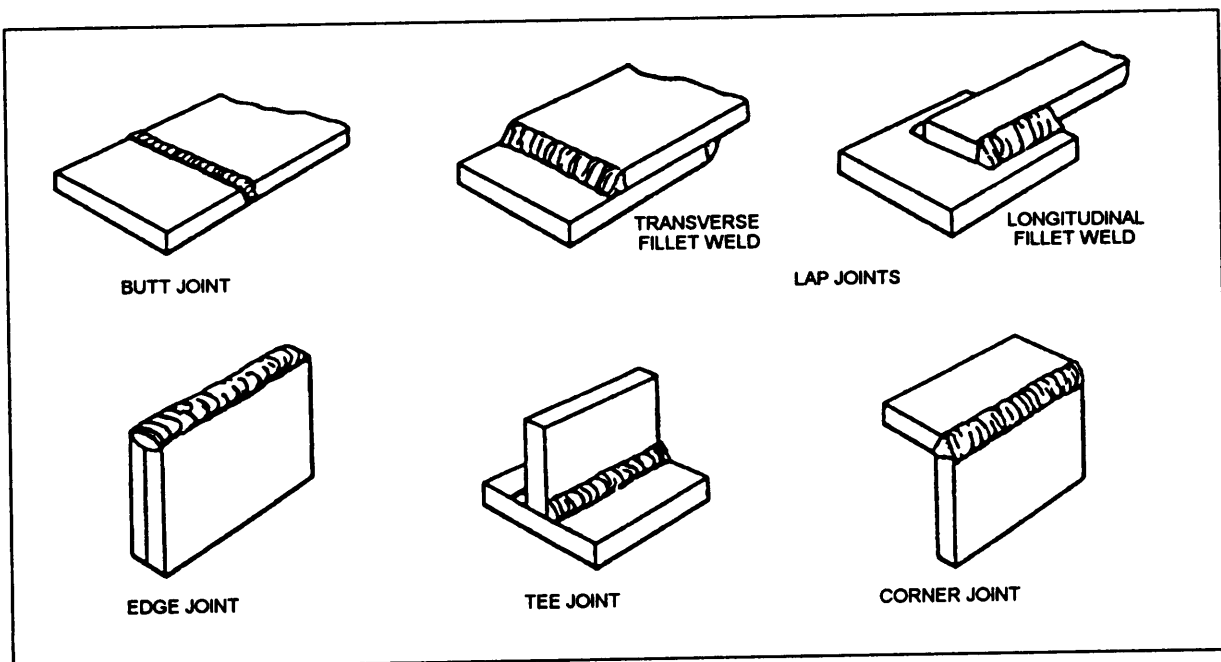


Figure 1-49.—Welded joints.

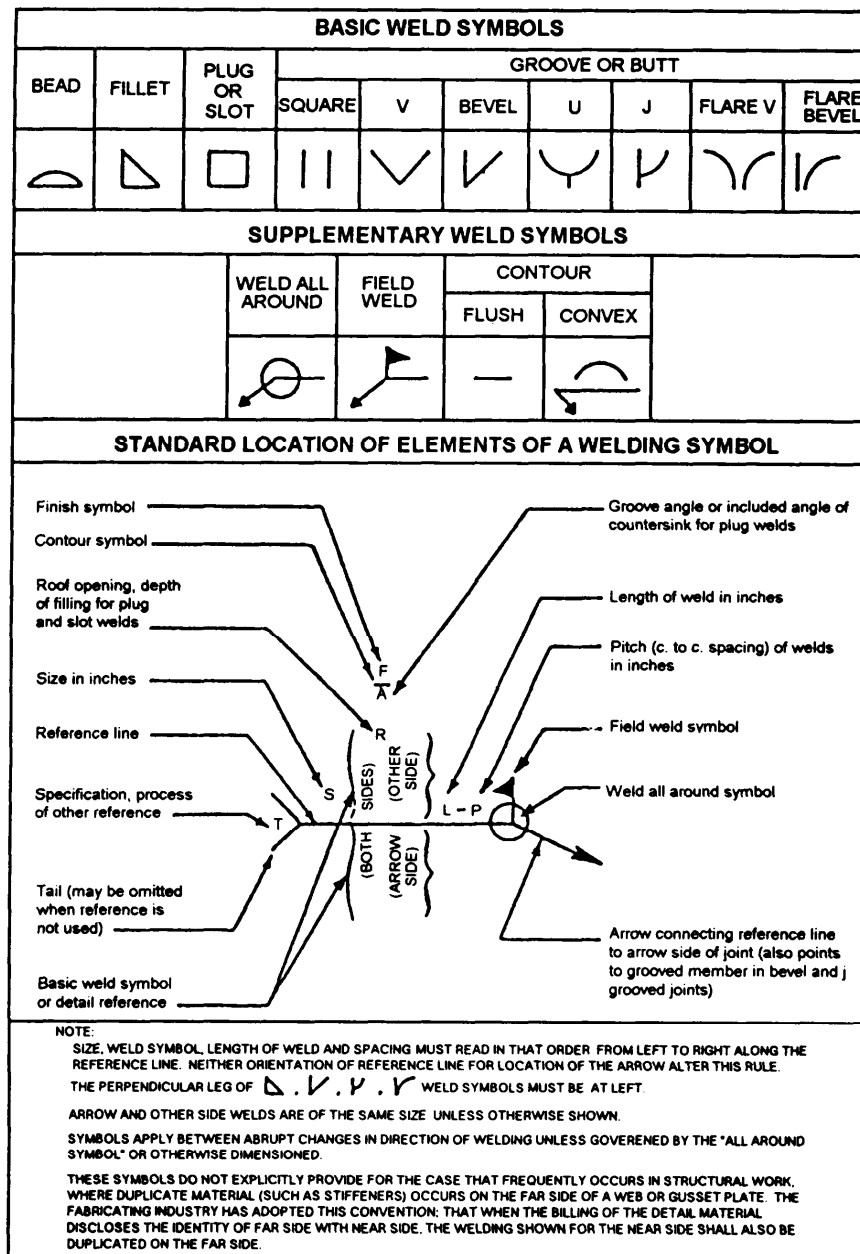


Figure 1-50.—Standard symbols for welded joints.

Figure 1-51 shows the use of a welding symbol. This figure shows a steel-pipe column that is to be welded to a baseplate. The symbol identifies to the welder that the type of weld to be used is a fillet weld, that the weld is to extend completely around the pipe-to-column joint, and that the weld is to be made in-place in the field rather than in a fabrication shop.

A detailed explanation of welding symbols and their usage is contained in *Symbols for Welding and Nondestructive Testing*, ANSI/AWS A2.4-86. Welding

terms and definitions are found in *Standard Welding Terms and Definitions*, ANSI/AWS A3.0-89.

Pins

Pins for very large structures are manufactured especially for the type of job and may have diameters of 24 inches or more and be several feet in length. For most types of jobs, however, pins are between 1 1/4 inches and 10 inches in diameter. The two types of pins commonly used are threaded-bridge pins and cotter

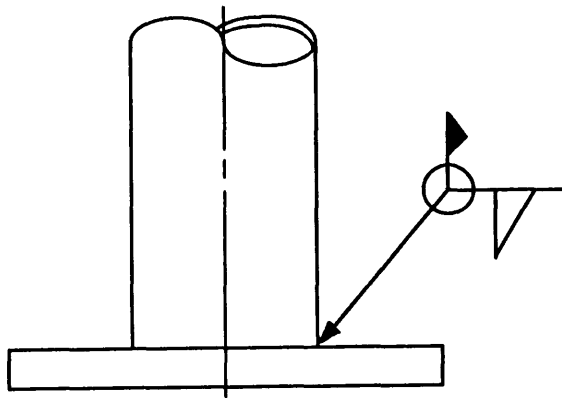


Figure 1-51.—Example of a welding symbol in use.

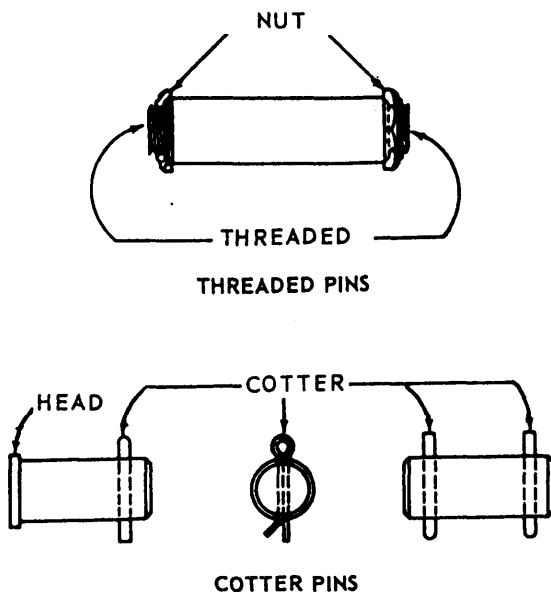


Figure 1-52.—Pins for structural steel connections.

pins. (See fig. 1-52.) **Threaded pins** are held in place after insertion by threaded recessed nuts on both ends of the pin. **Cotter pins** are held in place by small cotters that pass through holes drilled in the pins. Washers and separators, made from lengths of steel pipe, are used to space members longitudinally on pins. Holes for small pins are drilled; larger pinholes are bored.

Rivets

Rivets are manufactured of soft steel in various nominal sizes and lengths. The sizes most often used in structural work are 3/4 inch and 7/8 inch in diameter. The lengths differ according to the thickness of materials to be connected. Rivets are inserted in the rivet

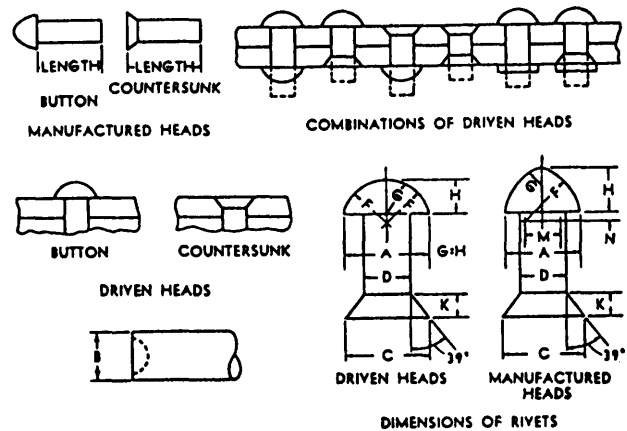


Figure 1-53.—Structural rivets.

holes while the rivet is red hot; consequently, the holes are drilled or punched 1/16 inch larger in diameter than the nominal diameter of the cold rivet.

Rivets are manufactured with one whole head already fixed. The rivet shank is cylindrical and the second head is formed by driving it with a pneumatic hammer. The rivet set, which is inserted in the end of the hammer, has a cavity of the proper shape to form the head of the rivet. Most Structural rivets are two full heads (fig. 1-53). Manufactured heads of rivets may also be obtained in countersunk shape to fit into holes countersunk in the material to be connected. When a driven countersunk head is to be formed, the rivet is driven with a flat-ended rivet set to fill the countersunk cavity in the material.

QUESTIONS

The following questions are strictly for your use in determining how well you understand the topics discussed in this chapter AND IN THE REFERENCES SPECIFICALLY CITED IN THIS CHAPTER. The intent of these questions is to help you learn the topics contained in the chapter and in the references. Remember, when you participate in the advancement examination for EA2, you may be asked questions that are drawn not only from this TRAMAN, but from the cited references as well. Therefore, it is to your benefit to answer the review questions. You do NOT have to submit your answers to these review questions to anyone for grading. Similar review questions will be included at the end of each chapter of this TRAMAN. After answering the questions, you may turn to appendix VI of this book to see how well you performed.

- Q1. *What are the three principal types of abutments used for fixed bridges?*
- Q2. *Other than the material used, what is the difference between a timber pile bent and a steel pile pier?*
- Q3. *In general, what are the three essential elements that are common to all foundations?*
- Q4. *What type of pile is used to resist lateral loads?*
- Q5. *What is the name of the breakwater that serves a dual function as a wharfage structure?*
- Q6. *Between a W12 x 50 structural steel shape and an S12 x 50 shape, which one provides the greater strength? Why?*
- Q7. *Define wall-bearing construction.*
- Q8. *In a preengineered metal building, what is the primary purpose of the girts?*